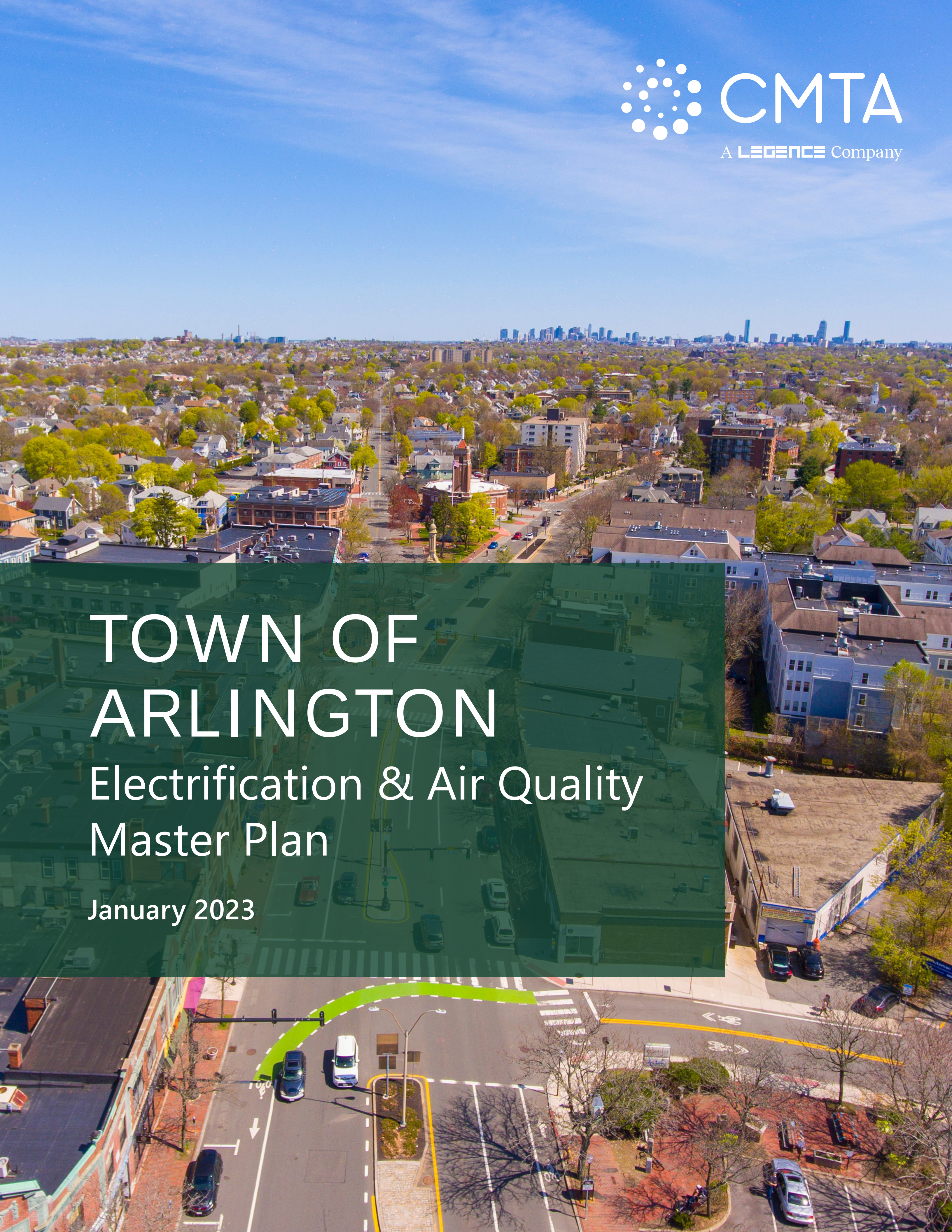

CMTA
A LEGENCE Company

TOWN OF ARLINGTON

Electrification & Air Quality Master Plan

January 2023

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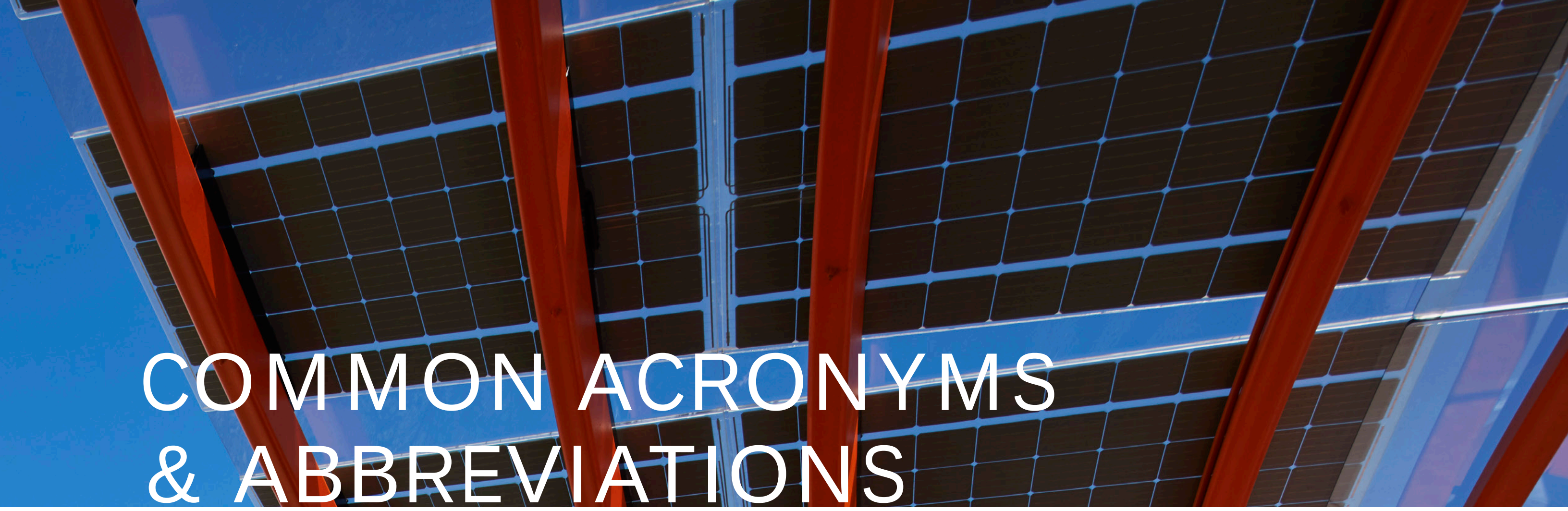


COMMON ACRONYMS & ABBREVIATIONS

AHU: Air Handling Unit

APS: Arlington Public Schools

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers

BAS: Building Automation System

BERDO: Boston Emissions Reduction Disclosure Ordinance

CMTA: Consulting engineering firm, hired for this study

Cx: Commissioning

DOAS: Dedicated Outdoor Air System

Dx: Direct Expansion Cooling

EPA: Environmental Protection Agency

EUI: Energy Use Intensity, building efficiency measured in thousands of British Thermal Units per square foot per year (kBtu/SF/yr)

GHG: Greenhouse Gases

GHI: Global Horizontal Irradiance

HVAC: Heating, Ventilation, and Air Conditioning

IRA: Inflation Reduction Act

ISO-NE: Independent System Operator New England, the New England electric grid

ITC: Investment Tax Credit

kBTU: Kilo British Thermal Units, unit for energy

kWh: Kilowatt Hour, unit of energy

LCCA: Life Cycle Cost Analysis

LED: Light Emitting Diode

MSBA: Massachusetts School Building Authority

MTCDE: Metric Tons of Carbon Dioxide Equivalent

NREL: National Renewable Energy Laboratory

NZAP: Net Zero Action Plan, a publication by the Town of Arlington released in February of 2021

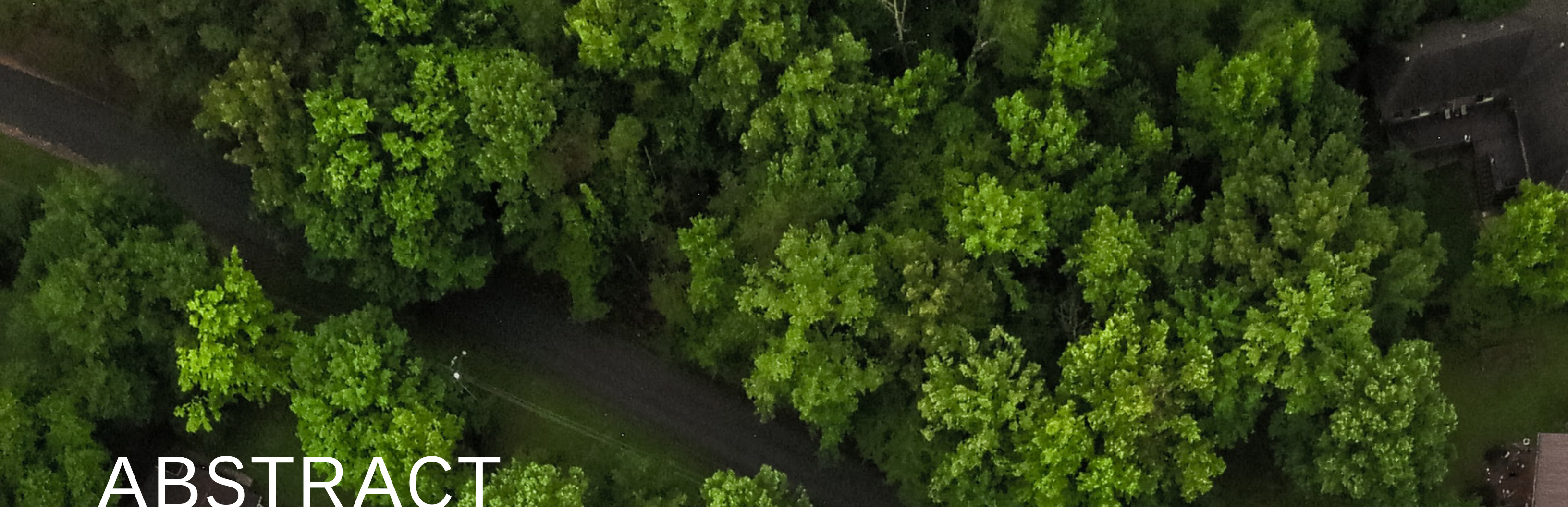
PV: Photovoltaic

RTU: Rooftop Unit

VRF: Variable Refrigerant Flow

EXECUTIVE SUMMARY

ABSTRACT
GOALS & OBJECTIVES
SUMMARY OF FINDINGS
THIRTY YEAR LIFE CYCLE COSTS
STRATEGIC ROADMAP
FUNDING FLOWS



ABSTRACT

The rate of change of carbon dioxide levels in the atmosphere is unparalleled. The US Energy Information Administration estimates 5.1 billion metric tons of energy related carbon were emitted in 2019 in the United States. Buildings are responsible for 40% of this energy consumption. Proactive efforts to improve new and existing building stock, like the Town of Arlington's 2021 Net Zero Action Plan (NZAP), released in February of 2021, will play a huge role to mitigate climate change. The Town of Arlington has pledged to reduce greenhouse gas (GHG) emissions to net zero emissions by 2050. The Town's NZAP recommends that all Town buildings be made fully electric, and that all municipal electricity be supplied from renewable sources.

Electrifying will achieve a reduction in local combustion and thus GHG emissions at the Town level. Importantly, a reduction in combustion improves air quality, which has community health benefits. The negative impacts of poor outdoor air quality include heart attacks, asthma attacks, bronchitis, hospital and emergency room visits, work and school days lost, restricted activity days, respiratory symptoms, and premature mortality.

Arlington Public Schools (APS) understands the link between air quality and wellness, and has committed to providing healthy and productive learning and working environments for all students, faculty, staff and visitors. The Town's building electrification goal will support improved indoor air quality by reducing exposure to on-site fossil fuel burning and/or energy consumption. In addition, APS's goal of improving air quality and ventilation, while ensuring comfortable temperatures, will improve learning and working environments while also minimizing the spread of COVID-19 and other airborne illnesses.

The Town of Arlington commissioned CMTA, Inc. to prepare a comprehensive Electrification and Air Quality Master Plan focusing on engineering and economic analyses of current and proposed heating, cooling, ventilation, and air filtration systems for Bishop Elementary, Brackett Elementary, Hardy Elementary, Peirce Elementary, Dallin Elementary, and Ottoson Middle School. Studying these six schools was in direct response to the NZAP and health concerns raised by the COVID-19 pandemic. This Master Plan provides a comprehensive roadmap that will help the Town chart a course to achieve ambitious targets at the six school buildings.

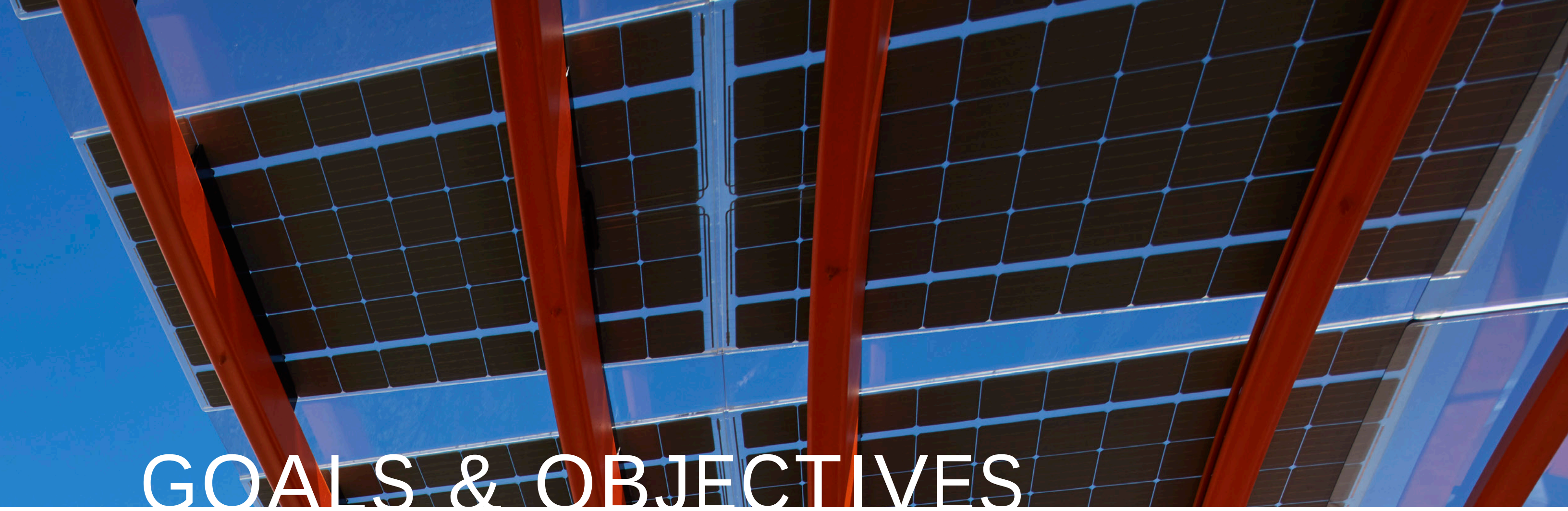
The Master Plan is broken down into three phases:

Phase I – Building System Inventory and Assessment

Phase II – Alternative Electrification and Air Quality Improvement Options

Phase III – Investment Plan

The authors commend these actions towards adopting more sustainable facilities. We would like to extend a special thanks for the support from Town personnel Jim Feeney, Talia Fox, Robert Behrent, Fergal O'Brien, and Ken Pruitt for their assistance during the preparation of this Master Planning Document.



GOALS & OBJECTIVES

The purpose of this Master Plan is to develop a path forward for six schools in the Town of Arlington to achieve net zero GHG emissions by the year 2050. The Town's NZAP recommends the electrification of all Town buildings, but this study focuses on these six schools because they have not been recently renovated. Therefore, electrification could occur within the cycle of regularly scheduled capital upgrades. In addition to electrification, achieving the Town's goals will require capital investments to achieve drastic reductions in both energy demand and consumption. The study also addresses occupant satisfaction and wellness, focusing on heating, cooling, ventilation, and air filtration system concerns raised by the COVID-19 pandemic.

Key over-arching goals and objectives for this Master Plan include:

1. Develop timelines and cost estimates to eliminate fossil fuel consumption and electrify and improve indoor air quality at six school buildings per the Town's 2021 (NZAP). This involves heating, ventilating, and air conditioning (HVAC) systems, domestic water heating, and kitchen/foodservice functions.
2. Establish options, feasibility, and priorities for drastic energy reductions and electrification at each site while adding air conditioning and mechanical ventilation throughout. Discussions with the Town narrowed the options for all electric HVAC systems to either a variable refrigerant flow system or a ground source heat pump system. These choices do not reflect all options for electrified systems, but offer the study of an air-cooled system type and a water-cooled system type. Hybrid options exist but were not studied.
3. Provide a practical evaluation of on-site photovoltaics that enables the Town to take the next steps for budgeting and planning purposes. Attaining on-site net zero energy is not required.

For the Town to reach its stated goal of carbon neutrality by 2050, there are several programs of investment to consider for direct and indirect carbon emission reductions, including:

1. Investment in physical infrastructure, deferred maintenance, and efficiency improvements that leverage utility incentives, where applicable. An emphasis on increasing overall efficiency and thoughtful system design is critical in making electrification financially viable.
2. Investment in on-site renewable energy sources to lower energy costs and reduce emissions associated with electricity production (while the electric grid still uses some fossil fuels), where feasible.
3. Purchase of renewable energy credits to offset any remaining electricity-related emissions.
4. Leverage the tax provisions of the Inflation Reduction Act of 2022 allowing state and local governments to receive "direct pay" tax credit reimbursements for ground source heat pump and solar photovoltaic (PV) systems.

SUMMARY OF FINDINGS

The intent of the study was to identify options for the Town to electrify five elementary schools and Ottoson Middle School. This includes evaluating electrification and renewable energy options, providing cost data, and suggesting the order in which improvements at each school should be implemented. Throughout the process, CMTA and the Town have agreed that the key to electrification is to focus on energy efficiency and energy reduction first. Following efficiency improvements, systems can be electrified and remaining GHG emissions can be offset through the purchase of offsets or installation of clean energy generating systems because the Town has limited real estate to install solar PV systems. After careful evaluations of PV ownership, the Town noted that procuring offsets may be more viable following electrification of all buildings and before the grid becomes 100% clean. The Town aims to achieve net zero emissions but does not seek to achieve net zero energy. Specific energy conservation measures are recommended in the Phase II section of this report.

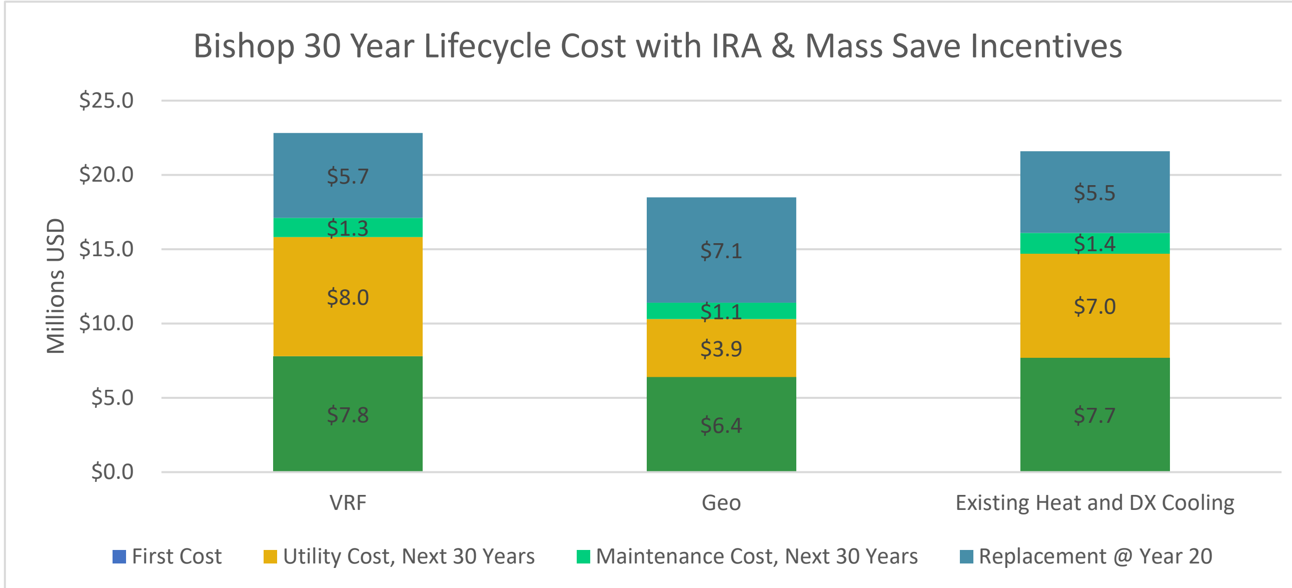
This Master Plan evaluated two options: a variable refrigerant flow system and a ground source heat pump system. These two systems were selected to represent an air source and water source option. Although hybrid options exists, other systems were not evaluated based on limitations in scope. For each of the systems, a conceptional design was completed. The narrative and zoning diagrams associated with each system are available in Appendices A and B. Equipment cut sheets were solicited from vendors and are available in Appendix C. These informed a cost estimation exercise. The results are available in Appendix D.

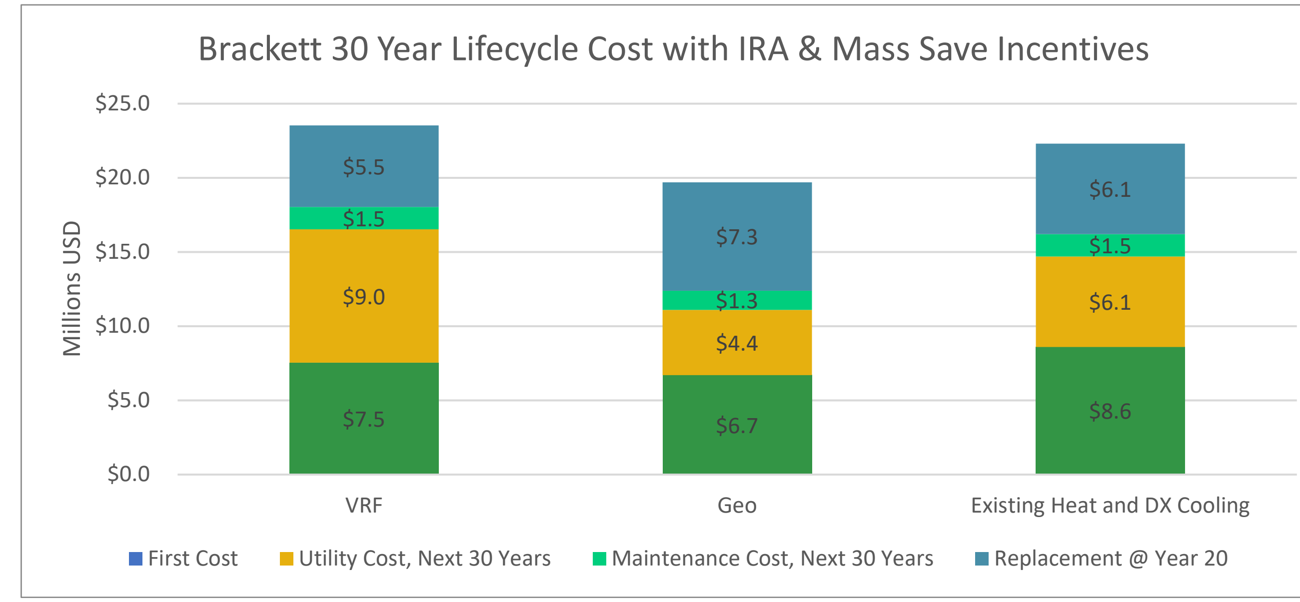
System selection is not within the scope of this Master Plan. The analysis in the Phase III section of this report is meant to provide the Town with data to make an informed decision. Three cases were analyzed: a variable refrigerant flow (VRF) option, a ground source heat pump option, and a business as usual option. The business as usual case maintains existing gas heat and adds air conditioning via direct expansion (DX) cooling. This offers a point of comparison for the minimum cash flows that would be required to upkeep existing systems and add mechanical cooling to the schools.

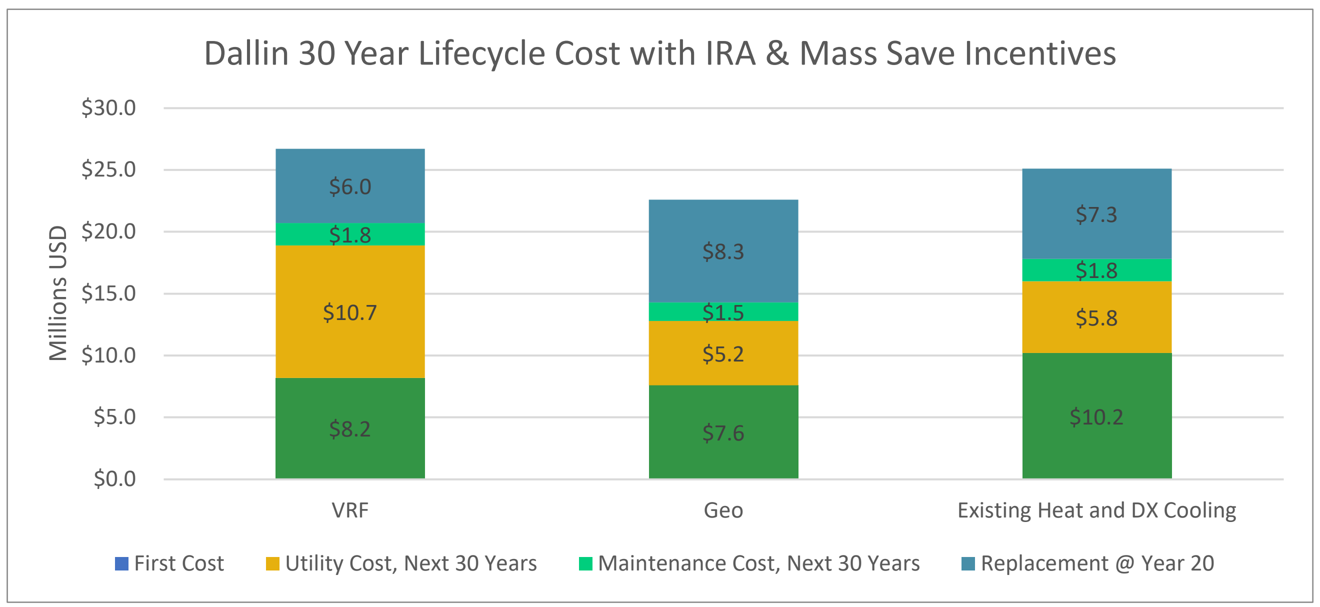
CMTA recommends selecting a system based on life cycle cost, rather than first cost. A 30 year life cycle cost analysis (LCCA) was performed and includes: intial project costs to design and install an all-electric system, utility costs, maintenance costs, and 20-year partial replacement costs. The LCCA also includes the estimated incentives from the Inflation Reduction Act and the MassSave incentive program run by New England utilities. See the stacked bar charts reflecting these costs for each of the schools on the following page. Details on methodology and assumptions are available in the Phase III portion of this report. The trends show that ground source heat pump systems are more expensive than VRF when comparing first cost, but more affordable over the system lifespan, even moreso when incentives are considered. For instance, the geothermal IRA incentives for Ottoson and Bishop almost cover the cost to upgrade Brackett. See the stacked bar charts reflecting these costs for each of the schools on the following page.

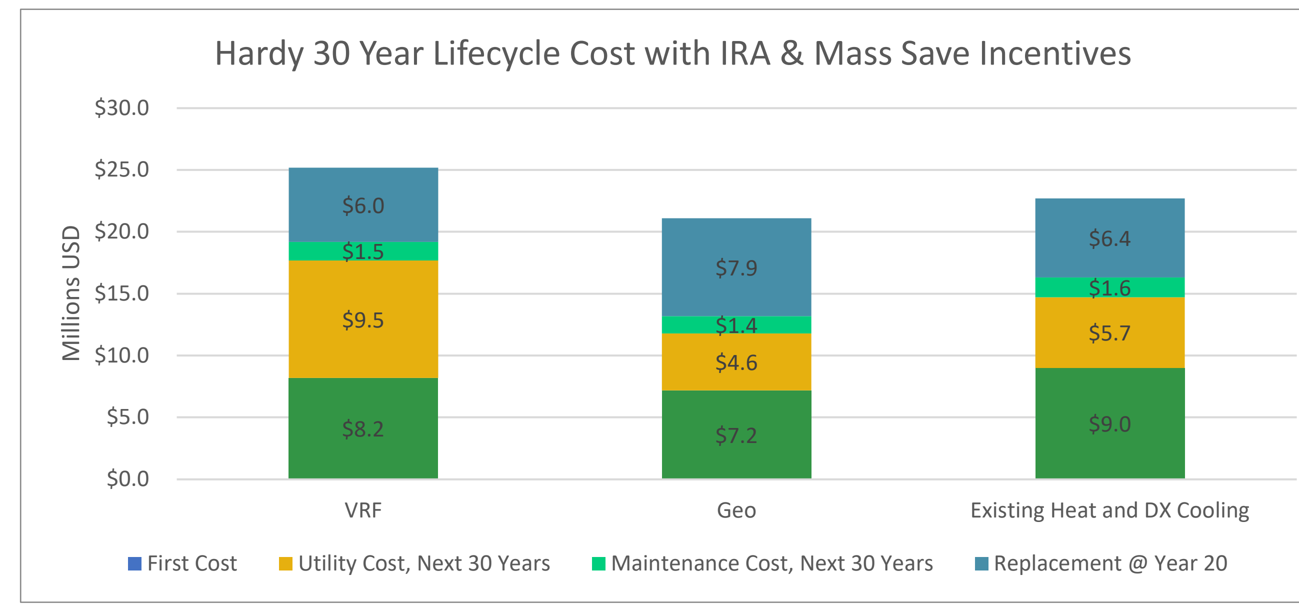
Using the information gathered in Phases I and II, the CMTA team developed a framework to establish a recommended order for school renovation, shown in the Strategic Roadmap on page nine. This study recommends that Ottoson Middle School seek Massachusetts School Building Authority (MSBA) funds for a more comprehensive building renovation before funds are invested in an HVAC electrification retrofit.

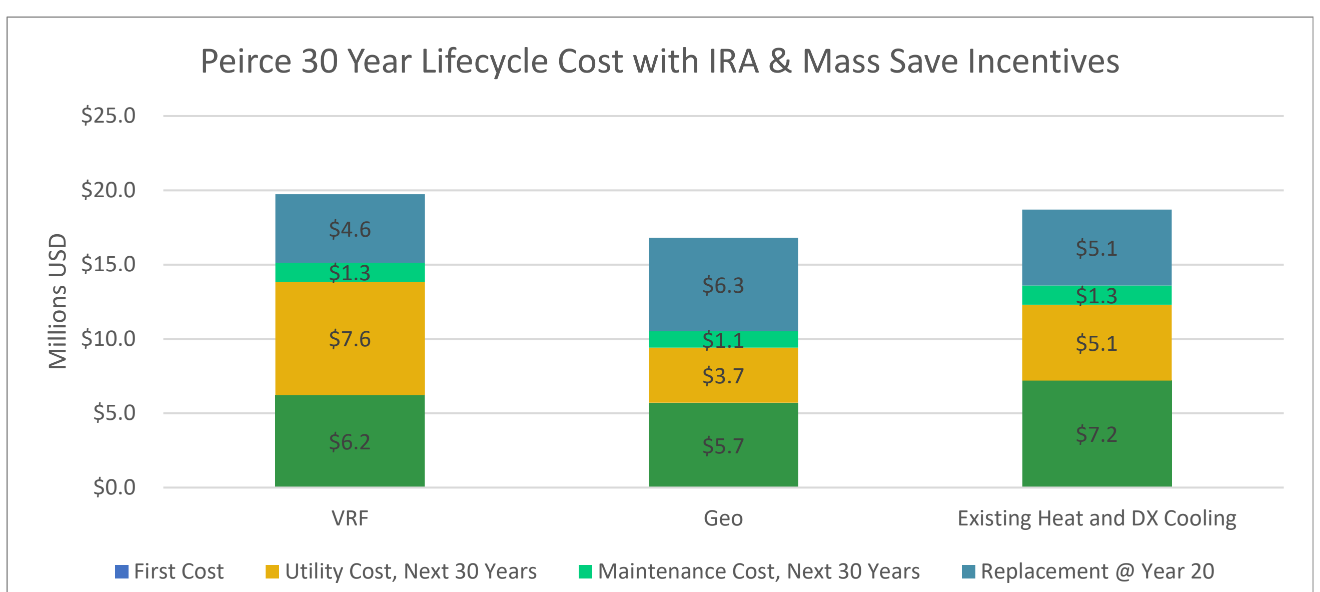
30-YEAR LIFE CYCLE COST WITH IRA & MASS SAVE

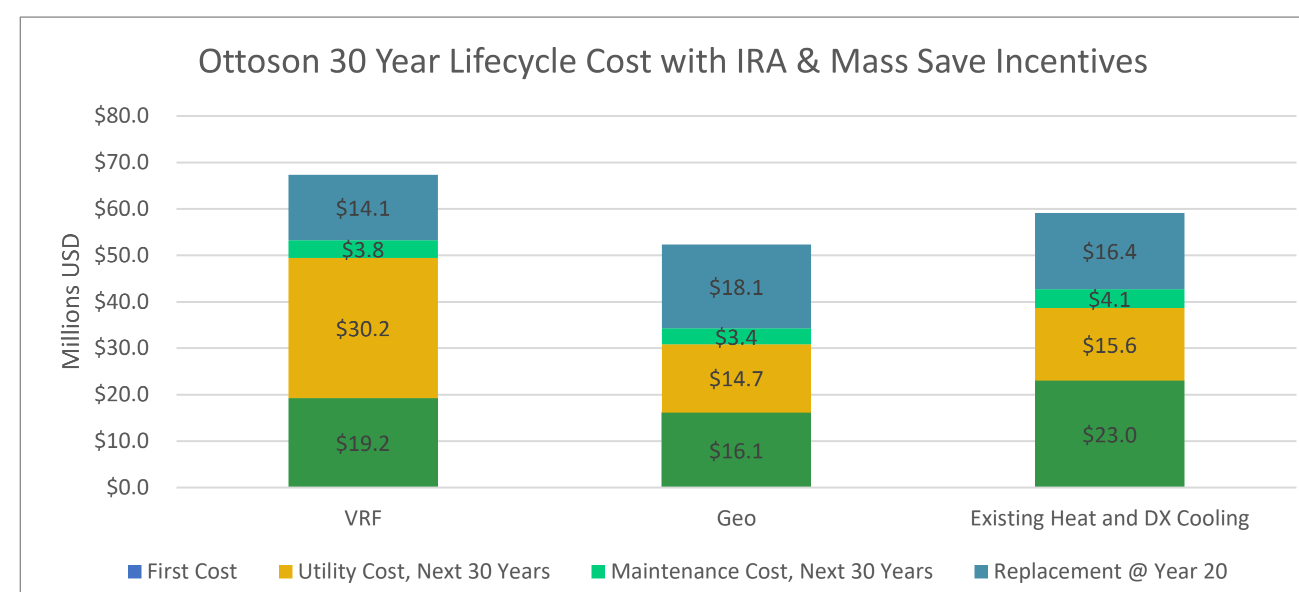




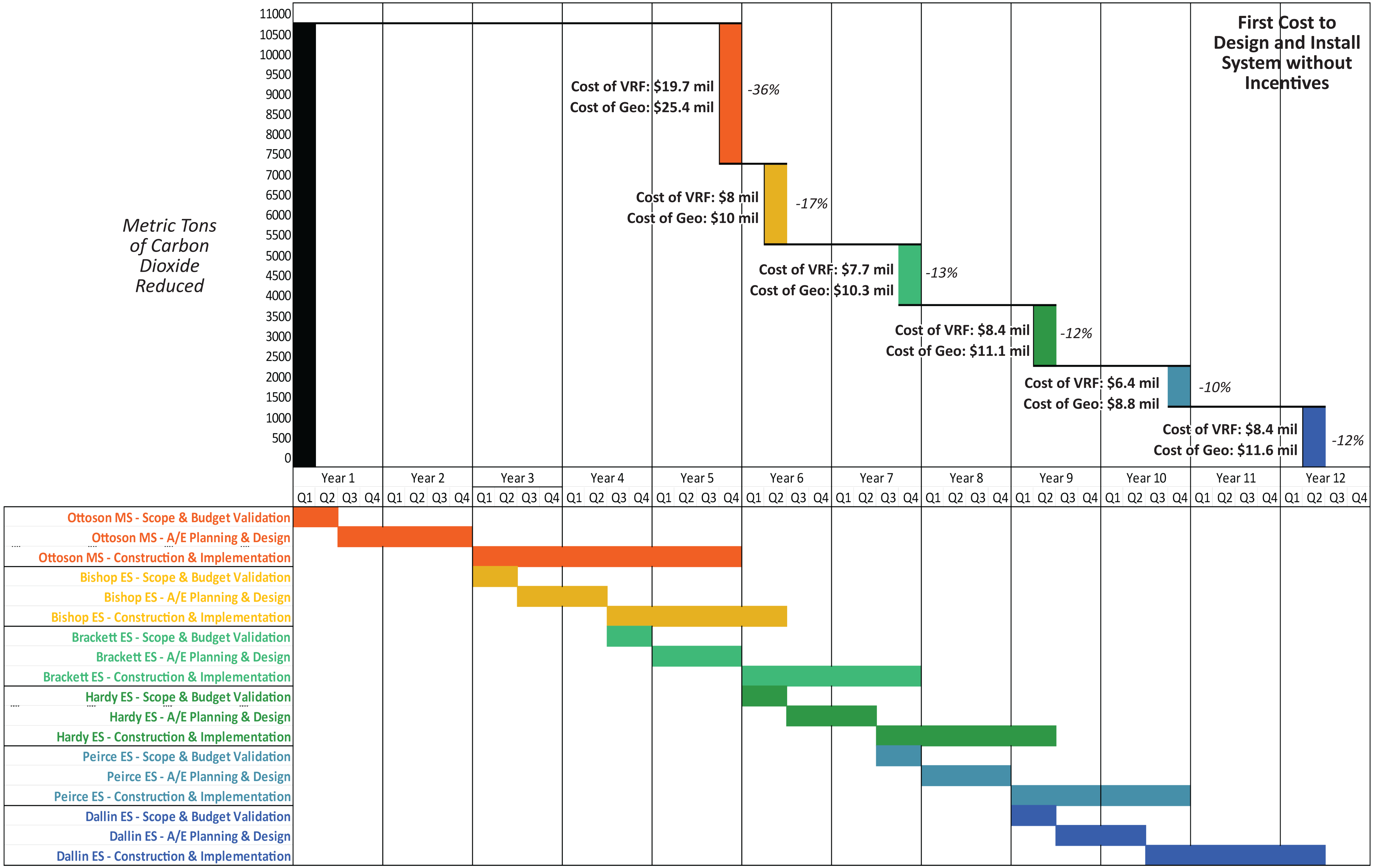








STRATEGIC ROADMAP



The analysis presented optimized the ranking and sequencing of projects based on order of magnitude of cost, emissions reduction potential, and need for infrastructure renewal. These recommendations are detailed in the Phase III section of this report. While the established goal of electrification by 2050 may seem far in the future, when considering the project scope to retrofit six schools, factoring in the design and construction period, as well as the planning for funding outlays of this magnitude in advance, the Town ishould initiate this process early. The chart above is the culmination of all three phases. It shows the recommended project phasing, the impact project completion would have on site emissions in the Town of Arlington, and the first cost for each viable, fully electrficed option.

FUNDING FLOWS

	Variable Refrigerant Flow		Ground Source Heat Pump	
	Spend	**Rebate/Incentive**	**Spend**	**Rebate/Incentive**
Year 1				
Ottoson MS	$ (19,700,000.00)		$ (25,400,000.00)	
Year 2				
Year 3				
Bishop ES	$ (8,000,000.00)		$ (10,000,000.00)	
Year 4				
Brackett ES	$ (7,700,000.00)		$ (10,300,000.00)	
Year 5				
Year 6				
Hardy ES	$ (8,400,000.00)		$ (11,100,000.00)	
Ottoson MS Mass Save Incentive		$ 438,000.00		$ 1,655,000.00
Ottoson MS IRA Incentive		$ -		$ 7,600,000.00
Year 7				
Peirce ES	$ (6,400,000.00)		$ (8,800,000.00)	
Bishop ES Mass Save Incentive		$ 169,000.00		$ 599,000.00
Bishop ES IRA Incentive		$ -		$ 3,000,000.00
Year 8				
Brackett ES Mass Save Incentive		$ 151,000.00		$ 548,000.00
Brackett ES IRA Incentive		$ -		$ 3,100,000.00
Year 9				
Dallin ES	$ (8,400,000.00)		$ (11,600,000.00)	
Year 10				
Hardy ES Mass Save Incentive		$ 195,000.00		$ 586,000.00
Hardy ES IRA Incentive		$ -		$ 3,300,000.00
Year 11				
Peirce ES Mass Save Incentive		$ 159,000.00		$ 459,000.00
Peirce ES IRA Incentive		$ -		$ 2,600,000.00
Year 12				
Dallin ES Mass Save Incentive		$ 189,000.00		$ 529,000.00
Dallin ES IRA Incentive		$ -		$ 3,500,000.00
Totals	$ (58,600,000)	$ 1,301,000	$ (77,200,000)	$ 27,476,000
Net Spend	**$**	**(57,299,000)**	**$**	**(49,724,000)**

The table above demonstrates the first cost allocations and expected incentives for each system. First cost represents the cost for either system in year one of a project. For any incentives, disbursment is typically allocated one year after the project is completed. The delay reflects the estimated time required to conduct a cost segregation study.

PHASE I
BUILDING SYSTEM INVENTORY & ASSESSMENT

PHASE I OBJECTIVES

The CMTA team spent time at each of the six school facilities to gain a general understanding of the existing conditions of the buildings. We visually spot checked the major systems and recorded details of each building to understand the installation and operations including the HVAC systems, building management systems, air filtration, main electrical services, and domestic water heating systems.

During the site visits, CMTA performed a high-level review of the building envelope (roofs, walls, windows) and reviewed potential implementation strategies for new HVAC systems as defined in Phase II. Additionally, the carbon emissions, energy use intensity, and cost intensity of each of the sites were benchmarked using annual utility data provided by the Town.

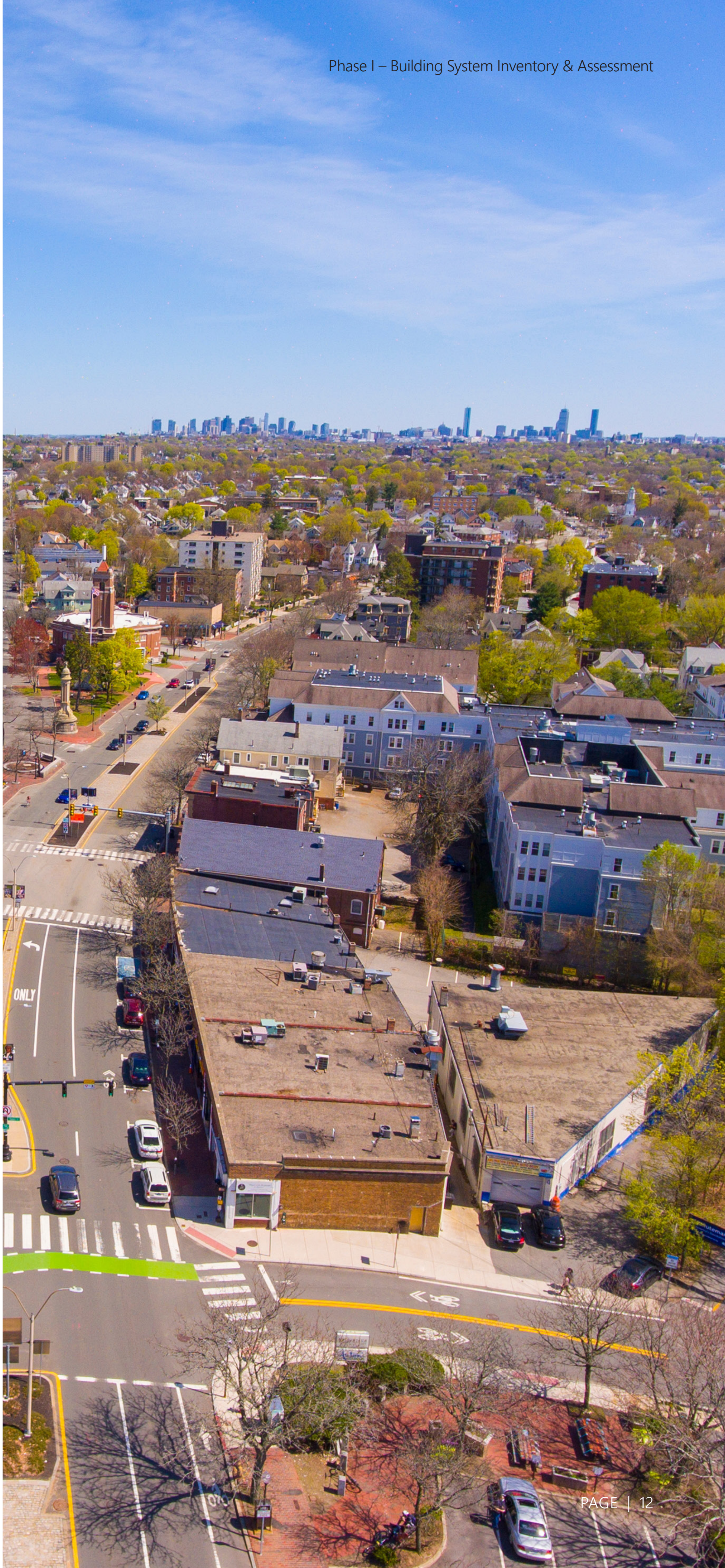
The scope of Phase I did not include the following items:

a. Detailed and comprehensive inventory of HVAC equipment including makes, model numbers, capacities, distribution and zoning, filtration, control sequences, warranties, life expectancies, maintenance histories, etc.
b. Detailed and comprehensive inventory of electrical equipment including number and locations of panelboards, transformers, circuit breakers (used and unused), warranties, life expectancies, maintenance histories, etc. Additionally, electrical metering was not performed.
c. Computerized energy modeling, building management trend reviews or test and balance surveys.

About the Town of Arlington

The Town of Arlington is a suburban community located in Middlesex County, approximately six miles northwest of Boston. Arlington covers 3,518 acres, or 5.5 square miles. Arlington's population is 46,844 (2020 US Census). A total of 5,755 students are served by the district across 11 public school buildings: the six schools that are the subject of this Master Plan as well as Arlington High School, the Gibbs Middle School, Menotomy Preschool, and the Thompson and Stratton elementary schools.

The Town has a history of setting and achieving sustainability goals starting with its first climate action plan, the Arlington Sustainability Action Plan (ASAP), adopted in 2005. The ASAP called for a 10% reduction in greenhouse gas (GHG) pollution by 2010, and 20% by 2020, and the Town achieved both. Arlington is a state-designated Green Community. Beginning in 2018, it became a member of the Metropolitan Mayors Coalition, which commits the Town to achieving net zero GHGs by 2050. The Town is currently in the process of enacting the necessary steps to meet the goals of the 2021 Net Zero Action Plan.



About the Schools

The general physical conditions of the five elementary schools were good, while conditions at Ottoson Middle School were fair. Across the six schools, windows were generally observed to be double-paned and operable. There were a few instances of blown seals and many instances where the windows were observed open. Most site visits occurred in early 2022 on days where the temperatures ranged from 15-35 ^{o}F. The open windows suggested there are some thermal comfort issues but could also be a remnant of COVID-19 precautions.

In all schools, air gaps were observed around exterior doors, leading to unnecessary air infiltration. Examples appear in ***Figures 1 and 2*** on the right.

All roofs were observed visually in good condition for their ages, which ranges from 17-24 years old.

The mechanical systems are well maintained but aged and past useful life. All schools currently have gas-fired boilers and no school has complete central air conditioning. There are a few individually air-conditioned offices and classrooms across the six schools.

The electrical infrastructure is also in good condition. With well-designed HVAC systems, the service size should be able to support the proposed electrification in all but two schools: Bishop and Hardy Elementary.

All schools have partially upgraded lighting. All external lights and a portion of internal lights have been converted to LEDs.

Equipment in the kitchens is not completely utilized as the food is now centrally prepared at Thompson Elementary School. Accordingly, the kitchens at each of the six schools studied are used primarily for warming rather than preparing food, which enhances kitchen efficiency and overall school efficiency.

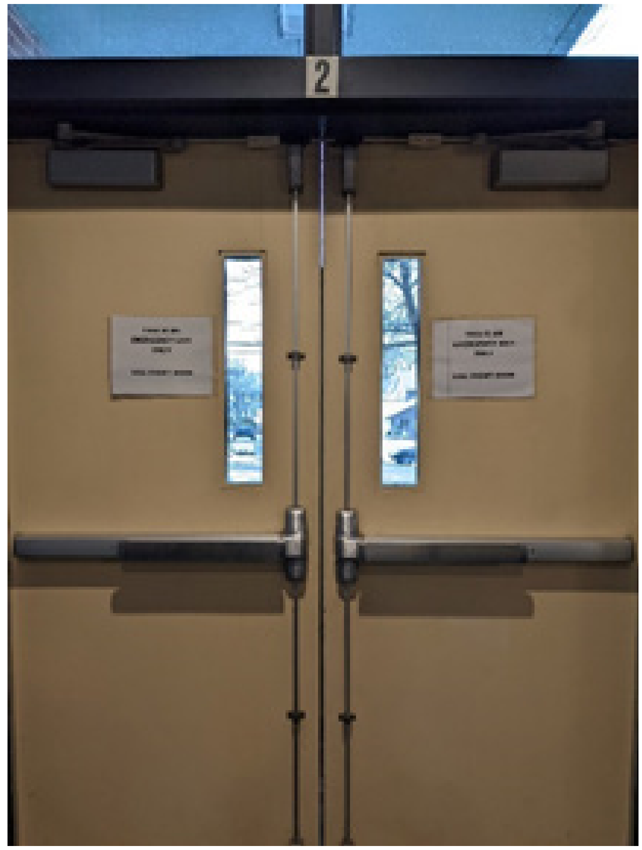


Figure 1 and 2 *Example Infiltration at Peirce Elementary School*

Baseline Energy Profile & Emissions

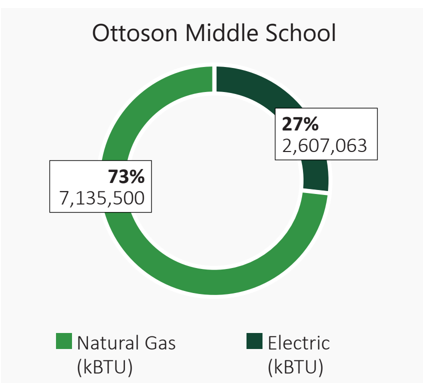
The following is a summary of the pre-electrification energy of each school. This data acts as a baseline to which future improvements can be compared. This section will describe the baseline energy use, energy use intensity, energy cost, and emissions for the six school buildings.

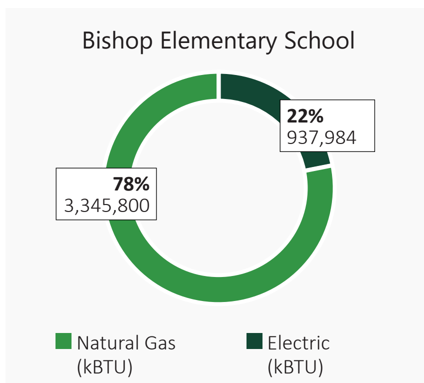
Energy Use

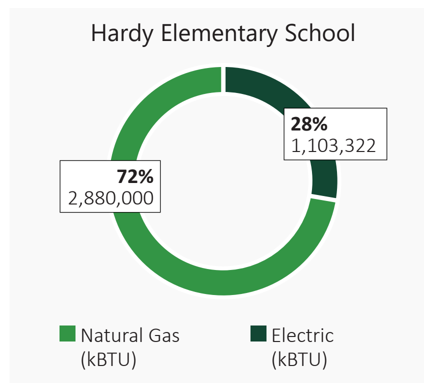
In 2019, for the six schools, the Town paid a combined ~$811,000 for utilities, with electricity accounting for 72% and gas accounting for the remaining 28% of the total cost. Aggregate annual utility costs come to $1.84 per square foot.

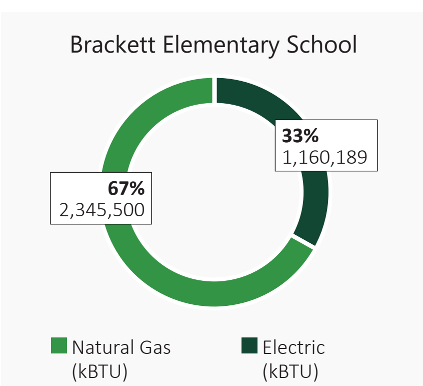
The following charts show the proportion of electricity verses natural gas consumption in 2019. For ease of comparison, both sources of energy have been converted from their native units, kilowatt hours (kWh) and therms, to kilo British thermal unit (kBTU).

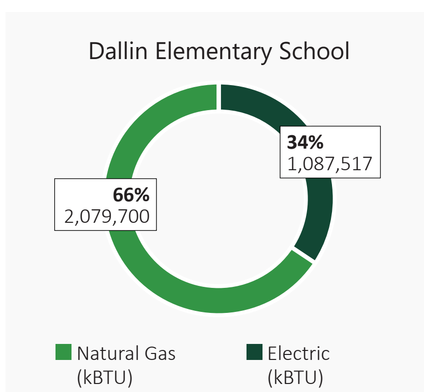
School Energy Consumption of Gas vs. Electricity (2019)

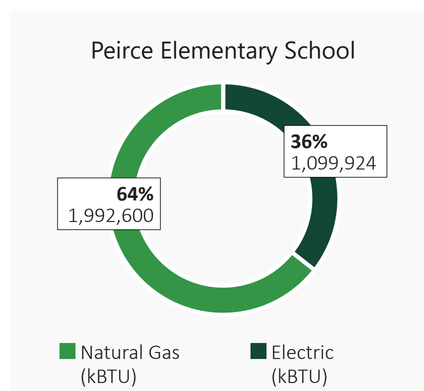






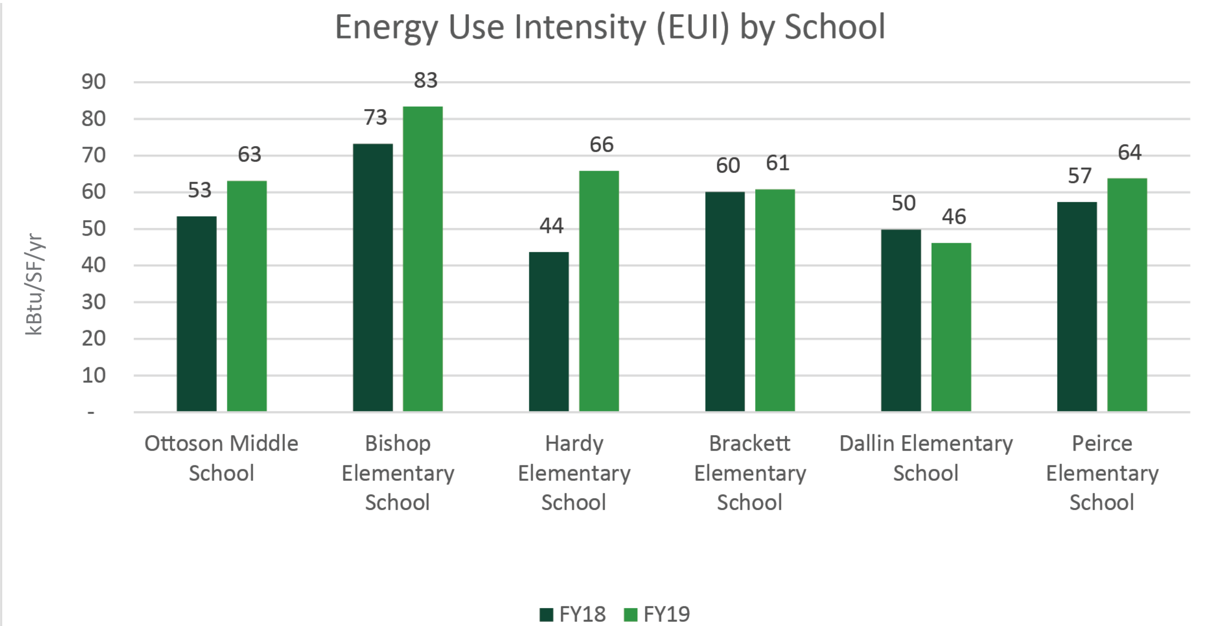




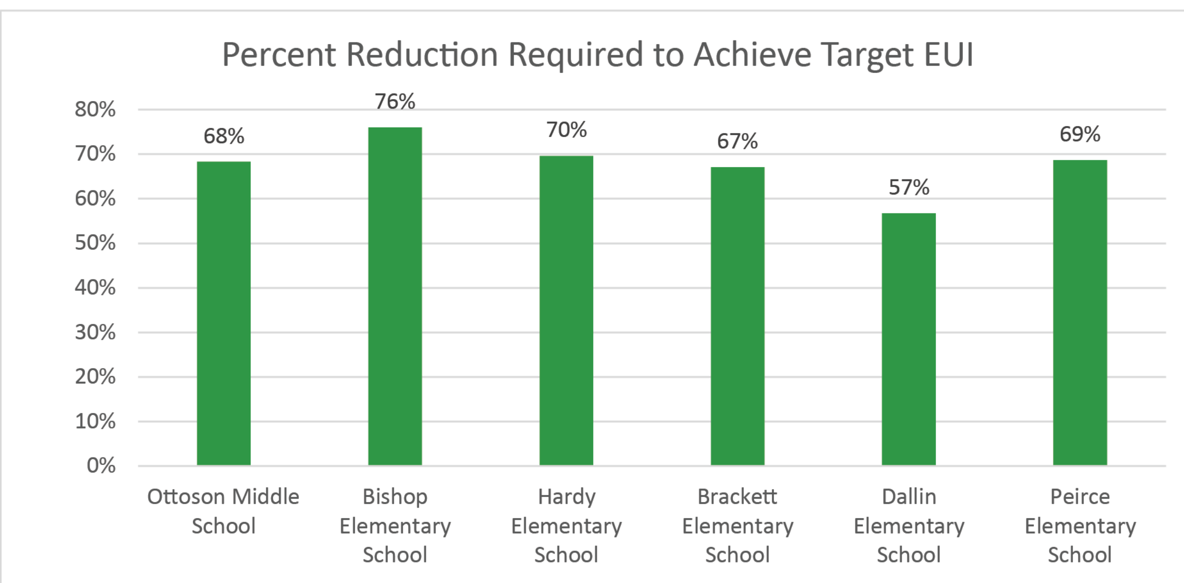


Energy Use Intensity

Building efficiency is measured in thousands of British Thermal Units per square foot per year (kBtu/SF-yr). This metric is referred to as Energy Use Intensity (EUI). This allows the energy consumption for buildings of various sizes to be fairly compared with a normalized metric. The lower the EUI, the better. Arlington's six schools operated at a site EUI ranging from 44-83 kBtu/SF/yr in fiscal years 2018 and 2019, as depicted in the graph below.



A net zero energy school would also be net zero emissions. For comparison to the current school EUIs, the target EUI for a net zero energy school is 20-25. For the six schools in this study to reach that target EUI range, overall energy would need to be reduced. As shown in the chart below, to achieve the net zero target EUI of 20-25, the total energy consumption of each school would need to be reduced 57-76%.



Energy reduction required when comparing the current building EUI with the target EUI required for net zero energy

Utility Rates and Costs

Arlington currently utilizes two primary energy sources for its school buildings: electricity and natural gas.

Arlington's electricity distributor is Eversource. Arlington has a fixed-price (no separate capacity charge) competitive electricity contract with Constellation that expires in December 2024. Arlington negotiates new competitive supply contracts approximately every three years.

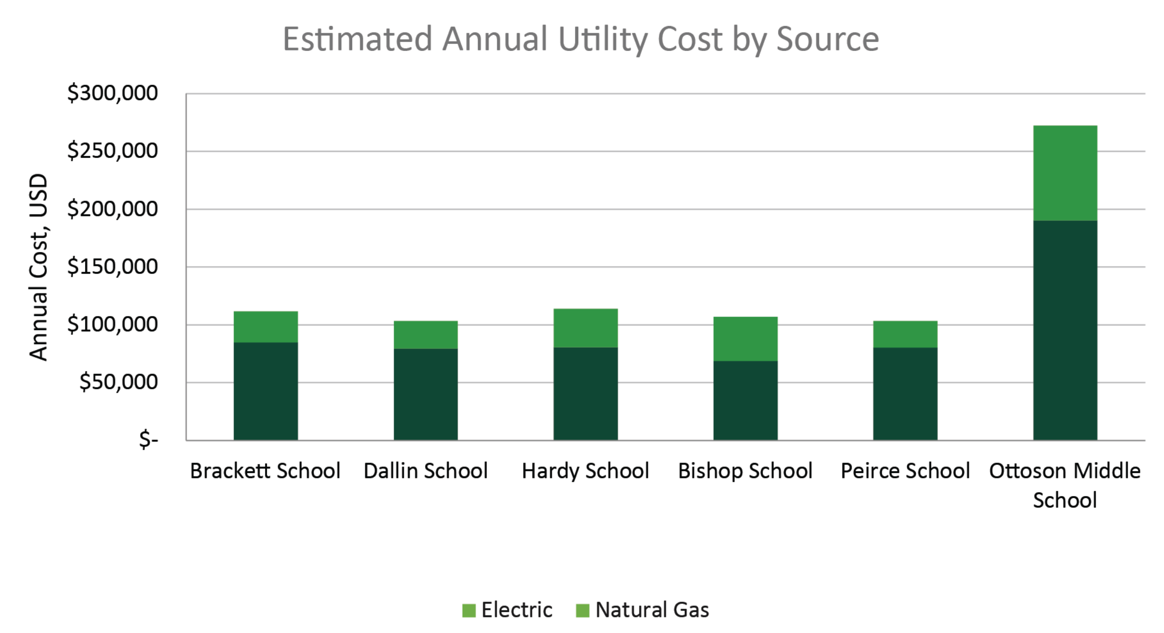
Arlington's natural gas distributor is National Grid. Arlington has a competitive gas supply contract with Direct Energy that expires in October 2024. Arlington negotiates new competitive supply contracts approximately every three years. Recent rates for both utilities, as provided by Town staff, are below.

Utility	Time Period	Supply Rate
Electricity	Dec 2019 – Dec 2022	$0.1023 / kWh
	Dec 2022 – Dec 2023	$0.0862 / kWh
	Dec 2023 – Dec 2024	$0.1285 / kWh
Natural Gas	Jan 2020 – Dec 2022	$0.573 / therm
	Jan 2023 – Oct 2024	$0.492 / therm

When accounting for supply and delivery, the blended rates for FY22 are shown below. These are the average across the six schools included in this analysis.

Blended Rate	
Electricity	Natural Gas
$0.2491 / kWh	$1.15 / therm

Most of the utility costs for each school are from the electricity. The consumption distribution is the converse; a majority of the energy is from natural gas while it accounts for a minority of the costs. This is a well-known market condition. The approach of this study is efficiency first, then electrification. This will enable the Town to achieve its sustainable electrification goals without prohibitive costs. The graph below shows the estimated annual utility cost for each school by energy source, using the blended rate and FY2019 energy use.



Emissions Analysis

Emissions are quantified based on fuel portfolio and annual consumption. Though the cost of electricity is higher, the emissions associated with electricity are lower. As more renewable energy comes online, grid emissions will continue to trend lower. Natural gas is the cheaper fuel, but it comes at the cost of higher levels of on-site pollution. The analysis below quantifies emissions based on EPA provided emission factors for electricity and natural gas consumption. The national emissions factor for electricity is 1 kilowatt hour = 0.000433 Metric tons of carbon dioxide equivalent (MTCDE). However, the Independent System Operator New England (ISO-NE) grid is cleaner than the national average, so this analysis utilized the ISO-NE regional value (below). Natural gas combustion occurs onsite and is thus not regionally dependent. The natural gas emissions factor is the national value. This value does not account for fugitive methane emissions.

ELECTRIC

1 kWh (kilowatt hour) = 0.00026 MTCDE (regional)

NATURAL GAS

1 therm = 0.00553 MTCDE (national)

For perspective on potential carbon cost, the analysis used the proposed “cost” of carbon, $234/MTCDE, as laid out in the Boston Emissions Reduction Disclosure Ordinance (BERDO 2.0). The BERDO program is from the same geographic region and is one of the most realized emissions strategies in the country. Using the 2019 utlity data and the BERDO carbon cost, the estimated cost of not electrifying or seeking clean power would be about $400,000 per year. Townwide emissions from the six schools are summarized in the table below.

TOTAL FOR 6 SCHOOLS STUDIED

Total Emissions

1,700 MTCDE

(2019 Baseline Emissions)

Equivalent Emissions

200 US Homes
(Over one year)

OR

400 Vehicles
(Driven over one year)

Offset Costs

$

$400,000/yr
Estimated annual cost of carbon offsets starting in 2030 if baseline emissions are not reduced, using the proposed BERDO $234/MTCDE.

The following page breaks out the emissions for each school in the study. The annual carbon footprint is shown in MTCDE and was calculated using utility data from 2019. Using 2019 data reflects typical energy consumption patterns, while more recent years did not reflect typical operating hours or control settings due to adaptations for the COVID-19 pandemic.

For each school, as for the total noted in the figure above the footprint was converted to more recognizable units, such as the emissions from an average US home or an internal combustion engine vehicle, driven for one year. This was done with the EPA’s greenhouse gas equivalency calculator.

Ottoson Middle School

600 MTCDE
(2019 Baseline Emissions)

Equivalent Emissions

75 US Homes
(Over one year)

128 Vehicles
(Driven over one year)

Bishop Elementary School

260 MTCDE
(2019 Baseline Emissions)

Equivalent Emissions

32 US Homes
(Over one year)

55 Vehicles
(Driven over one year)

Hardy Elementary School

240 MTCDE
(2019 Baseline Emissions)

Equivalent Emissions

31 US Homes
(Over one year)

52 Vehicles
(Driven over one year)

Brackett Elementary School

220 MTCDE
(2019 Baseline Emissions)

Equivalent Emissions

27 US Homes
(Over one year)

47 Vehicles
(Driven over one year)

Dallin Elementary School

200 MTCDE
(2019 Baseline Emissions)

Equivalent Emissions

25 US Homes
(Over one year)

43 Vehicles
(Driven over one year)

Peirce Elementary School

190 MTCDE
(2019 Baseline Emissions)

Equivalent Emissions

24 US Homes
(Over one year)

42 Vehicles
(Driven over one year)

Ottoson Middle School

63 Acton Street, Arlington, MA 02476

BUILDING HIGHLIGHTS

SIZE
- 154,380 SF
- 42 Classrooms
- 899 Students

CONSTRUCTION
- Constructed in 1920, major renovations in 1998

BUILDING ENVELOPE
- Windows are double pane
- Windows were open in many classrooms
- Roof replaced in 1998
- Infiltration through gaps in exterior doors

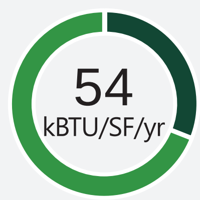
MECHANICAL EQUIPMENT
- Gas-fired domestic water (DW) heating and hot water (HW) heating boilers (x3)
- General Classrooms & Instructional Spaces – Heating Only Unit Ventilators (UV)
- Band, Cafeteria/Dining, Admin/Offices - Large DX A/C Rooftop Units (RTU) w/ Natural Gas Heat (Multizone & Single Zone)
- Media Center & Media Center Support Areas – Self-Contained DX Unit Ventilators & DX A/C RTUs
- Gyms, Shop, Locker Rooms – Heating and Ventilation Air Handling Units (AHU)

ELECTRICAL EQUIPMENT
- The current service is 4000A 3-phase 208/120V
- 9.3 W/SF, which is of adequate size
- Has 270 kW rooftop solar; there is room for additional installations

KITCHEN EQUIPMENT
- Kitchen currently used primarily for warming

ENERGY BENCHMARKING [2019 DATA]

Annual EUI



Electrical Usage
2,607,063 kBTU *(31% of EUI)*

Natural Gas Usage
5,741,500 kBTU *(69% of EUI)*

Greenhouse Gas Emissions
476.1 metric tons CO2e

49
Energystar Score

EQUIVALENT MEDIAN K-12 SCHOOL

Annual EUI

53.6
kBTU/SF/yr

EQUIVALENT ENERGYSTAR K-12 SCHOOL

Min. Annual EUI

40.5
kBTU/SF/yr

Bishop Elementary School

25 Columbia Road, Arlington, MA 02474

BUILDING HIGHLIGHTS

SIZE
- 51,367 SF
- 15 Classrooms
- 440 Students

CONSTRUCTION
- Constructed in 1950, major renovations in 2002

BUILDING ENVELOPE
- Significant air gaps at most exterior doors
- Windows are double pane
- Windows were open in many classrooms, many shades were drawn

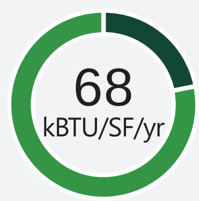
MECHANICAL EQUIPMENT
- Natural Gas-fired DW Heating and HW heating boilers (x2)
- General Classrooms & Instructional Spaces- Heating and Ventilating RTUs w/duct HW coils & w/ FTR
- General Classrooms & Instructional Spaces (Addition) – VRF with ERVs
- Admin, Offices, Media Center, Computer Lab- RTUs w/ split DX A/C coils & w/ duct HW coils
- Gym – Heating and Ventilating AHU

ELECTRICAL EQUIPMENT
- The current service is 1200A 3-phase 208/120V
- 8.4 W/SF, this ratio is low. A new service would likely be required.
- No onsite solar PV

KITCHEN EQUIPMENT
- Kitchen currently used primarily for warming

ENERGY BENCHMARKING [2019 DATA]

Annual EUI



Electrical Usage
937,984 kBTU (*27% of EUI)*

Natural Gas Usage
2,566,000 kBTU *(73% of EUI)*

Greenhouse Gas Emissions
197.9 metric tons CO2e

46

Energystar Score

EQUIVALENT MEDIAN K-12 SCHOOL

Annual EUI

65.6
kBTU/SF/yr

EQUIVALENT ENERGYSTAR K-12 SCHOOL

Min. Annual EUI

49.6
kBTU/SF/yr

Hardy Elementary School

52 Lake Street, Arlington, MA 02474

BUILDING HIGHLIGHTS

SIZE
- 60,507 SF
- 14 Classrooms
- 444 Students

CONSTRUCTION
- Constructed in 1926, major renovations in 2001
- 6-classroom addition in 2018

BUILDING ENVELOPE
- Significant air gaps at most exterior doors
- Windows are double pane
- Roof partially painted white for reduced heat gain
- Roof replaced in 2001

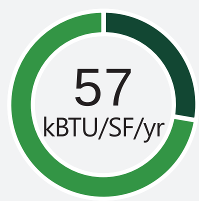
MECHANICAL EQUIPMENT
- Natural gas-fired DW heating and HW boilers (x2)
- General Classrooms & Instructional Spaces – Heating and Ventilating RTUs w/duct HW coils & w/ FTR
- General Classrooms & Instructional Spaces (Addition) – VRF with ERVs
- Admin, Offices, Media Center, Computer Lab- RTUs w/ split DX A/C coils & w/ duct HW coils
- Gym – Heating and Ventilating AHU

ELECTRICAL EQUIPMENT
- The current service is 1200A 3-phase 208/120V
- 7.1 W/SF, this ratio is low. A new service would likely be required
- There have been lighting retrofits including motion/ occupancy sensors
- No onsite solar PV

KITCHEN EQUIPMENT
- Kitchen currently used primarily for warming

ENERGY BENCHMARKING [2019 DATA]

Annual EUI



Electrical Usage
1,103,322 kBTU (*32% of EUI*)

Natural Gas Usage
2,370,200 kBTU (*68% of EUI*)

Greenhouse Gas Emissions
198.3 metric tons CO2e

54
energy
Energystar Score

EQUIVALENT MEDIAN K-12 SCHOOL	EQUIVALENT ENERGYSTAR K-12 SCHOOL
Annual EUI	Min. Annual EUI
60.1 kBTU/SF/yr	45.4 kBTU/SF/yr

Brackett Elementary School

66 Eastern Avenue, Arlington, MA 02476

BUILDING HIGHLIGHTS

SIZE
- 57,670 SF
- 20 Classrooms
- 535 Students

CONSTRUCTION
- Constructed in 2000, no major renovations

BUILDING ENVELOPE
- Windows are double pane, but a number of them had blown seals
- Many windows were open
- Roof replaced in 2000
- Infiltration through gaps in exterior doors

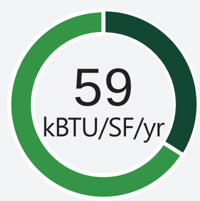
MECHANICAL EQUIPMENT
- Natural gas-fired domestic water heating and HW heating boilers (x2)
- General Classrooms & Instructional Spaces – Heating and Ventilating RTUs w/HW coils & w/ VAVs & w/ FTR
- Admin, Offices, Media Center, Computer Lab – DX A/C RTU w/ HW coil & w/ VAVs & w/ FTR
- Gym – Heating and Ventilating RTU w/HW coil

ELECTRICAL EQUIPMENT
- The current service is 1200A 3-phase 480/277V
- 17.3 W/SF, which is of adequate size
- Has been completely retrofit with LED lighting
- No onsite solar PV

KITCHEN EQUIPMENT
- Kitchen currently used primarily for warming

ENERGY BENCHMARKING [2019 DATA]

Annual EUI



Electrical Usage
1,160,189 kBTU *(34% of EUI)*

Natural Gas Usage
2,345,500 kBTU *(66% of EUI)*

Greenhouse Gas Emissions
195.1 metric tons CO2e

50

Energystar Score

EQUIVALENT MEDIAN K-12 SCHOOL

Annual EUI

59
kBTU/SF/yr

EQUIVALENT ENERGYSTAR K-12 SCHOOL

Min. Annual EUI

44.7
kBTU/SF/yr

Dallin Elementary School

185 Florence Avenue, Arlington, MA 02476

BUILDING HIGHLIGHTS

SIZE
- 68,578 SF
- 15 Classrooms
- 472 Students

CONSTRUCTION
- Constructed in 1956, major renovations in 2005

BUILDING ENVELOPE
- Significant air gaps at most exterior doors
- Windows are double pane
- Windows were open in many classrooms
- Roof replaced in 2005

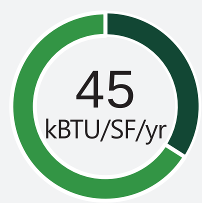
MECHANICAL EQUIPMENT
- Natural gas-fired domestic water heating and HW heating boilers (x3)
- General Classrooms & Instructional Spaces – Heating Only Unit Ventilators
- Cafeteria/Dining, Admin/Offices, Media Center- DX A/C Rooftop Units w/ Natural Gas Heat
- Gym – Heating and Ventilating AHUs

ELECTRICAL EQUIPMENT
- The current service is 1200A 3-phase 480/277V
- 14.5 W/SF, which is of adequate size
- Has 120 kW rooftop solar

KITCHEN EQUIPMENT
- Kitchen currently used primarily for warming

ENERGY BENCHMARKING [2019 DATA]

Annual EUI



Electrical Usage
1,087,517 kBTU *(35% of EUI)*

Natural Gas Usage
1,987,100 kBTU *(65% of EUI)*

Greenhouse Gas Emissions
176.5 metric tons CO2e

71

Energystar Score

EQUIVALENT MEDIAN K-12 SCHOOL

Annual EUI

56.5
kBTU/SF/yr

EQUIVALENT ENERGYSTAR K-12 SCHOOL

Min. Annual EUI

42.7
kBTU/SF/yr

Peirce Elementary School

85 Park Avenue Extension, Arlington, MA 02474

BUILDING HIGHLIGHTS

SIZE
- 48,500 SF
- 12 Classrooms
- 307 Students

CONSTRUCTION
- Constructed in 2002, no major renovations

BUILDING ENVELOPE
- Significant air gaps at most exterior doors
- Windows are double pane
- Windows were open in many classrooms

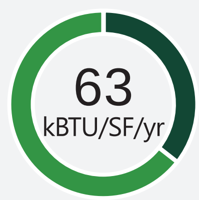
MECHANICAL EQUIPMENT
- Natural gas-fired domestic water heating and hot water heating boilers (x3)
- Air-Cooled Chiller
- General Classrooms & Instructional Spaces – 2-Pipe Heating/Cooling Unit Ventilators
- Cafeteria/Dining, Admin/Offices, Media Center – AHUs with Cooling
- Gym – Heating and Ventilating AHUs

ELECTRICAL EQUIPMENT
- The current service is 1200A 3-phase 480/277V
- 20.6 W/SF, which is of adequate size
- Has been completely retrofit with LED lighting
- Has 80 kW rooftop solar

KITCHEN EQUIPMENT
- Kitchen currently used primarily for warming

ENERGY BENCHMARKING [2019 DATA]

Annual EUI



Electrical Usage
1,099,924 kBTU (*36% of EUI)*

Natural Gas Usage
1,099,924 kBTU *(64% of EUI)*

Greenhouse Gas Emissions
176.3 metric tons CO2e

45

Energystar Score

EQUIVALENT MEDIAN K-12 SCHOOL

Annual EUI

60.1
kBTU/SF/yr

EQUIVALENT ENERGYSTAR K-12 SCHOOL

Min. Annual EUI

45.5
kBTU/SF/yr

PHASE II
ALTERNATIVE ELECTRIFICATION & AIR QUALITY IMPROVEMENT OPTIONS

PHASE II OBJECTIVES

This section describes options, feasibility, and priorities for drastic energy reductions and electrification at each site while adding air conditioning and mechanical ventilation throughout. As part of this effort, a Scoping Study Narrative (Appendix A), annotated PDF floor plans (Appendix B), cutsheets (Appendix C), and cost estimates (Appendix D) were prepared for each site. This portion of the Master Plan describes the technical approach necessary at a concept level for each school. Each of the schools will require significant minimum investment for HVAC system replacement in the next 20 years.

The basis of the Master Plan utilizes the following building information:

a. Bishop Elementary School – 51,370 SF
b. Brackett Elementary School – 57,670 SF
c. Dallin Elementary School – 68,580 SF
d. Hardy Elementary School – 60,510 SF
e. Peirce Elementary School – 48,500 SF
f. Ottoson Middle School – 154,400 SF

Additionally, increases in occupancy are not anticipated nor are building expansions included in this Master Plan. The CMTA team recommends that Ottoson Middle School undergo a more comprehensive update/renovation through the MSBA Capital Planning Process based on the overall age and condition of the building.

Two HVAC systems are considered in detail for each site: water-cooled, closed-loop ground source/geo-exchange HVAC and air-cooled variable refrigerant flow (VRF). An “in-kind” option that leaves existing natural gas heat and adds complete air conditioning is included to show the minimum investments that will be needed by the Town regardless of final HVAC system selection approach, recognizing that full renewal of existing systems will be needed in the near future. Both electrification approaches include total system renewal of equipment, piping ductwork, controls, etc. not just individual pieces of equipment.

The ground source HVAC system and VRF system options include full air conditioning and full heating. There are hybrid options available between the systems, and standing column geothermal wells could be considered, but these additional options were not included in this analysis. Both the ground source and VRF systems include mechanical dedicated fresh air ventilation complying with ASHRAE 62.1 and post-pandemic filtration strategies. Sizing of the HVAC system assumes air infiltration reduction measures but not major envelope upgrades. Also, alternatives to electrify domestic water heating are described and the food service approach of “warming kitchens” in the schools is assumed to remain – this is an effective strategy from an energy efficiency perspective.

The analyses of the systems incorporate first cost estimates, anticipated annual operating costs, and carbon emissions potential, in order to establish a life cycle cost investment. There are also potential utility incentives and federal tax dollars that may be available depending on the option chosen.

Path Forward to Electrification & Net Zero Emissions

The Town considered including a goal of net zero energy as well as net zero emissions, but ultimately that reality is limited by available real estate for PV systems and the feasibility of drastic energy reductions in existing buildings. A net zero energy building, as defined by the Department of Energy in its publication "A Common Definition for Zero Energy Buildings," is "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." In the industry, the goal EUI for a zero-energy building is the 20-25 EUI range, or better. This range represents a good ratio of program square footage, which drives energy consumption, to roof area, which typically limits the amount of PV that can be installed on site. To acheive an EUI in this range in an existing building will require drastic reductions in energy consumption. For the Arlington schools, based on the most recent energy data and the expectation of adding air conditioning to the buildings, this focus on energy efficiency first is especially necessary.

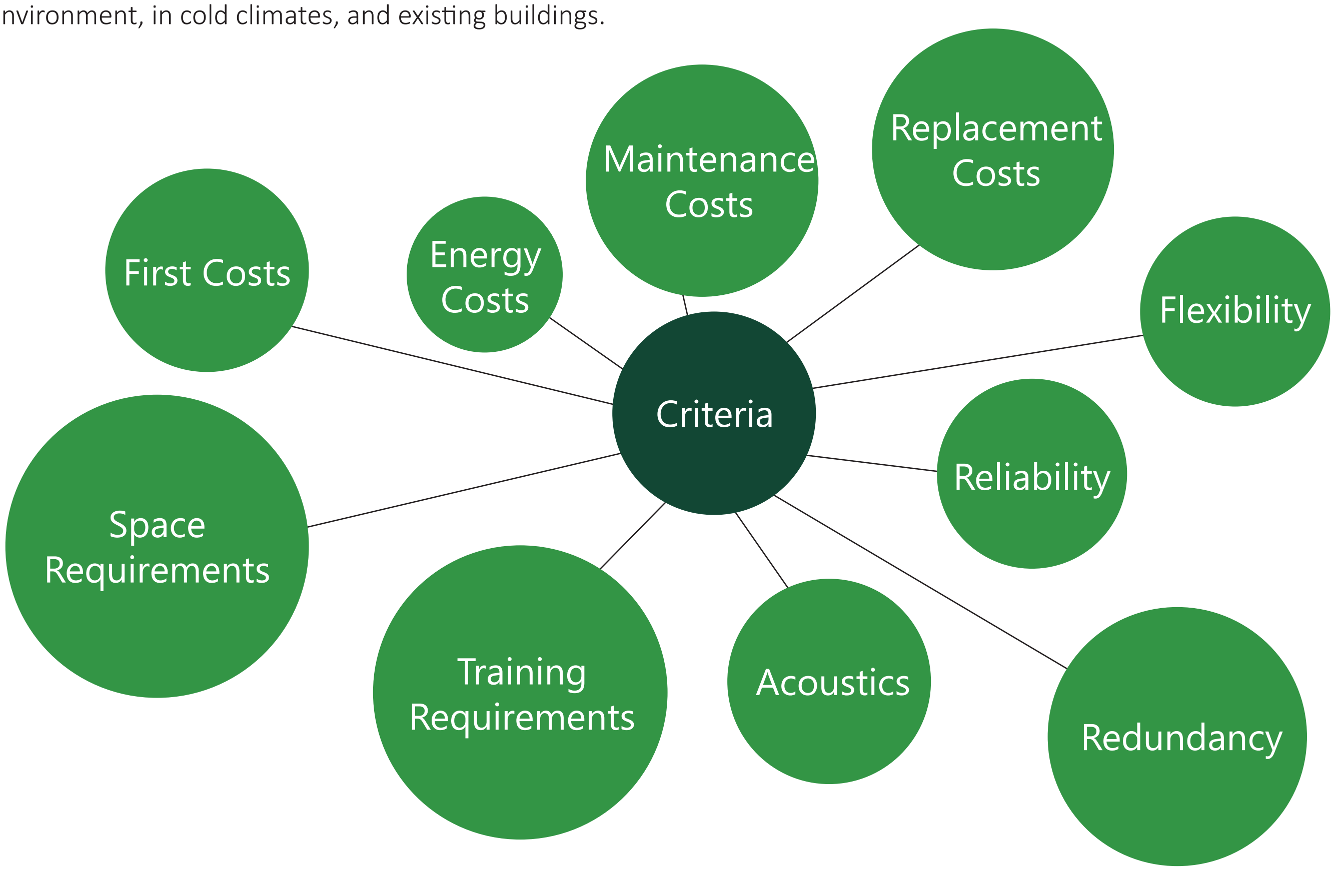
The following strategies, many of which the Town has taken, support energy reduction. Steps to enable the electrification of existing buildings:

1. Install highly efficient electrified heat pump type HVAC systems including controls and energy recovery strategies.
2. Install highly efficient LED lighting and controls.
3. Improve building envelope's thermal performance and reduce air leakage rates.
4. Install highly efficient electrified domestic hot water heating systems and implement water conservation strategies.
5. Manage plug loads including office equipment, technology systems and kitchen equipment and appliances.
6. Install additional on-site energy generation and/or purchase clean energy.
7. Verify the building performance through optimized commissioning efforts and consistently optimize building operations through long term measurement and verification.

Energy efficiency and reduction are central to net zero emissions as well as net zero energy, so each of these strategies has been considered in this study. Specific recommendations are broken out by building systems later in this section.

HVAC Electrification Alternatives

The largest operational cost impacts related to electrification will come down to the HVAC system selection. Several factors must be considered when selecting an HVAC system, as is depicted in the following diagram. There are several electric heat pump HVAC system options, but not all are a good fit when considering a K-12 environment, in cold climates, and existing buildings.



After conversations with the Town at the commencement of this study, it was decided that there would be two heat pump electrification options considered in this Master Plan. Both options will completely convert the natural gas-fired HVAC systems to electrified systems.

OPTION 1

Air-Cooled Variable Refrigerant Flow (VRF) HVAC System

This option consists of indoor cassette units, fan coils, etc. with outdoor VRF compressor heat pump units and interconnecting refrigerant piping for zone heating/cooling control. This system has a lower first costs, but higher life cycle costs. The predicted EUI for any school with this system will be ≈45 EUI.

OPTION 2

Water-cooled, Closed-loop Ground Source Heat Pumps

This option consists of unitary water-source heat pumps for zone heating/cooling control and an underground closed loop geothermal wellfield. This system has a higher first costs, but lower life cycle costs. The predicted EUI for any school with this system will be ≈22 EUI.

In response to COVID-19, both options include dedicated ventilation (outside) air systems to deliver preconditioned and highly filtered fresh air to all occupiable spaces.

Criteria Prioritization

There are many criteria by which the HVAC system could be chosen. The table below shows the parameters typically most important to school districts and how the two systems compare to one another.

	VRF	Geothermal
First cost	✓	X
EUI	X	✓
Program Implications/Space Required	✓	X
Speed of Construction	✓	X
Indoor Air Quality/Filtration	X	✓
Operating Cost	X	✓
Individual Zoning	✓	X
Emission Implications	X	✓
Fewer Compressors	✓	X
PV Impact	X	✓
Refrigerant Global Warming Potential (GWP)	X	✓

Parameters are explained below.

First Cost: The initial cost to purchase and install a new system.

The installation and equipment required for a VRF system is typically less expensive than a geothermal system.

EUI: The average Energy Use Intensity of an elementary school with this system type.

Geothermal heatpumps are a more efficient system and thus typically have a lower EUI than the same building with a VRF system.

Program Implication/Space Required: This refers to the total amount of equipment, its size, and the ideal location. In an existing building, there are are direct tradeoffs between mechanical/electrical space and program space.

In a VRF system, most equipment is confined to central mechanical rooms, above ceiling, and rooftops, meaning there is little reduction in program space. In geothermal heat pump systems, it is favorable for maintainance to locate the heat pumps in closets rather than above ceiling. Depending on the layout of the school, this can mean taking some area from program space.

Speed of Construction: The total time to install the system and return the space to operable conditions.

A geothermal system requires the drilling of a wellfield. This additional step means that VRF installations take less total time.

Indoor Air Quality: The quality of air in the building; related to the health and comfort of occupants.

Both systems can be equipped with air filters of the desired rating (post-COVID, this is typically MERV-13). However, because the heat pumps are installed in closets with separate doors to the hallway wherever possible, rather than above ceiling, they are more easily accessible for maintenance. In many cases, filter changes and other maintenance can be conducted more frequently without distrupting classrooms.

Operating Cost: The cost of utilities to operate the building.

Geothermal systems are more efficient than VRF, leading to lower energy consumption and decreased utility bills.

Individual Zoning: The degree to which occupants can control the thermal conditions of their space.

In geothermal systems, one to three zones share a heatpump, but individual airflow control per zone is still provided.

Emission Implications: The expected emissions based on the system type.

In this case, both systems would be all electric, so site emissions would be equivalent. However, at a source level, grid electricity is not yet 100% clean, so the better option is the one that uses the least electricity. As noted in the operating cost description, a geothermal system means higher efficiency, lower EUI, and less total energy consumption.

Fewer Compressors: This is based on the sum of all compressors required for either system.

Every heat pump includes a compressor, while a VRF system would only have compressors in the central outdoor equipment.

PV Impact: If striving for net zero energy, then a school would install an amount of PV capable of producing as much energy as the building consumes. The design and performance of the HVAC system is a large driver of the PV sizing.

The higher efficiency of the geothermal system means a smaller PV system would be required.

Refrigerant GWP: The global warming potential and amount of refrigerant required for either system.

Both systems could use the same refrigerant type, so the GWP would not vary. However, the VRF system is refrigerant based and thus requires a larger total amount of refrigerant. VRF also has more risk for leakage during field installation of refrigerants.

Phasing Recommendations

The culmination of the information gathered in Phases I & II is a weighted average computation. This method allowed quantitative assignments to be made across the key categories: Original Construction, Renovation, Equipment Condition, Energy Use Intensity, Carbon Footprint, and Current Operating Cost/SF. In each category, schools were ranked from 1-6 with 1 representing either the oldest, or worst condition and 6 the newest, or best condition. Ultimately, the data was condensed into three categories:

1. Need for Renewal: Based on the age of building and condition of infrastructure
2. Carbon Footprint: Based on total emissions using 2019 utility data
3. First Cost: Based on first cost of the existing heat and DX cooling case (1 is the highest cost, 6 the lowest cost)

Applying weights to the data allows for the conversion of qualitative comparisons to quantitative ones. Through discussions with the Town, it was decided to include Need for Renewal just above Carbon Footprint and First Cost, which resulted in weights of 40%, 30%, and 30%, respectively.

	1. Need for Renewal	2. Carbon Footprint	3. First Cost	Overall Rank
Bishop Elementary School	4	2	5	2
Brackett Elementary School	2	4	4	3
Dallin Elementary School	6	5	2	6
Hardy Elementary School	3	3	3	4
Peirce Elementary School	5	6	6	5
Ottoson Middle School	1	1	1	1*

The resulting order can be seen above. Ottoson is ranked first, but it is our recommendation that it be treated differently. Given the overall age of Ottoson, equipment, and the disparate layout of the various wings, an HVAC retrofit does not make sense as a standalone project. Funds invested to put a new HVAC system into the building would be better spent on a more comprehensive and integrated upgrade. In coordination with the MSBA, funds could be requested for said upgrade. With that note, the following is the recommended order to address the schools:

1. Ottoson Middle School (pending MSBA funding, Ottoson could change priority)
2. Bishop Elementary School
3. Brackett Elementary School
4. Hardy Elementary School
5. Peirce Elementary School
6. Dallin Elementary School

Clean Power

Existing Conditions

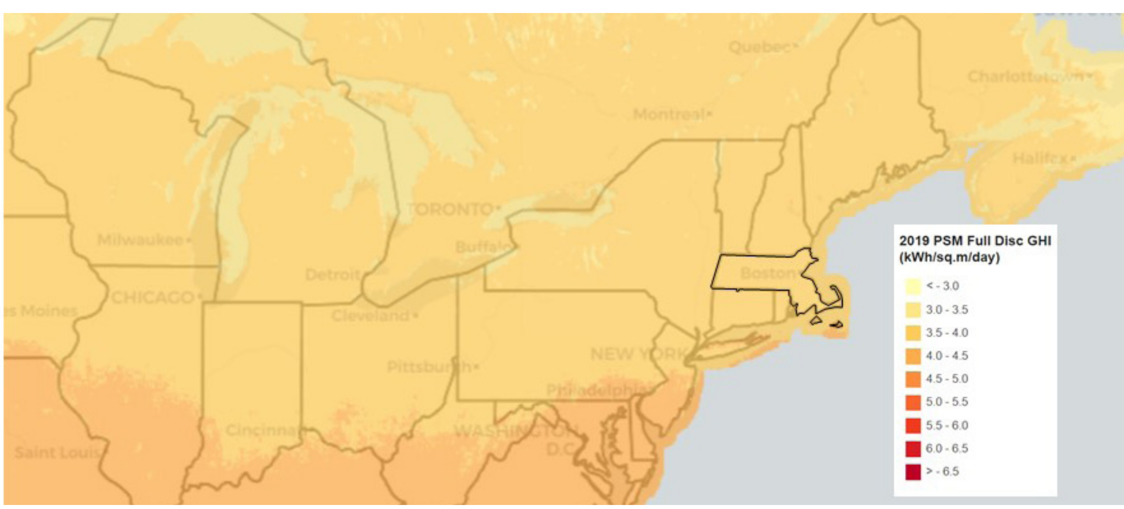
Three of the schools studied have existing PV installations: 120 kW at Dallin Elementary, 80 kW at Peirce Elementary, or the 230 kW at Ottoson Middle School. These are a part of a 2015, 20-year solar power purchase agreement with Ameresco. These installations are all in front of the meter and the Town does not claim the environmental offset.

A renovation of Arlington High School occurred in parallel with this Master Plan. During construction of that project, the rooftop panels had to be disconnected and temporarily relocated. The Town incurred fees for the period during which the panels were out of commission and not generating power. This was brought to the attention of the CMTA as a consideration for potential impacts on current or future rooftop solar at the six schools studied.

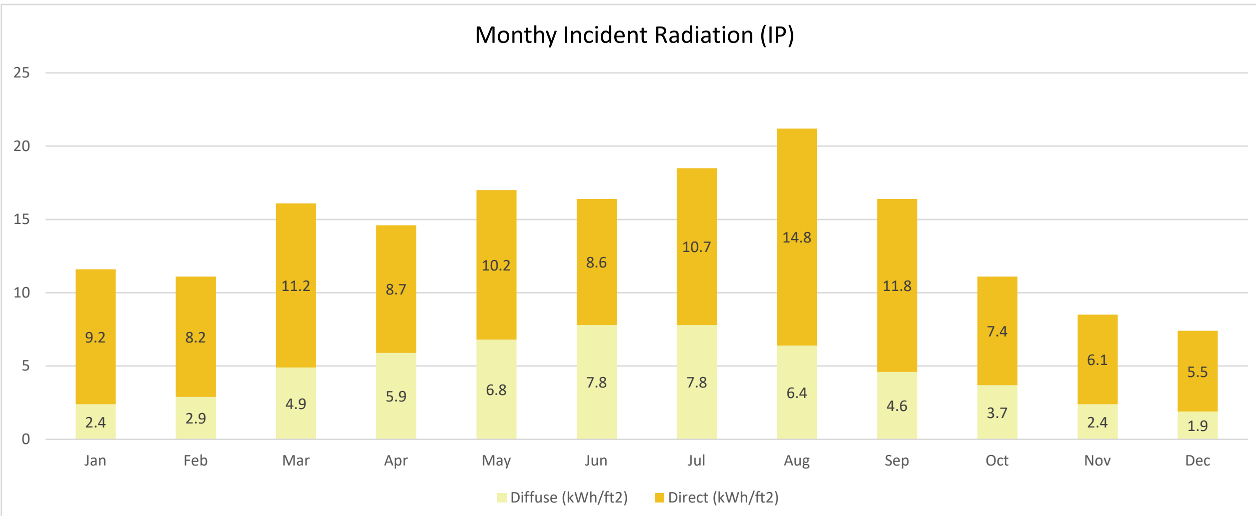
For those three schools with solar, electrification project construction could be conducted without long-term disruption to generation or the need for panel relocation. Temporary disconnects may need to occur when new equipment is being connected and short-term disconnection may be required if a service upgrade is deemed necessary. This would be confirmed in the design phase of each the projects. Regarding relocation, the removal of existing rooftop units is feasible without disruption of the PV installations. Based on dimensions from cutsheets for the new rooftop equipment, such as the dedicated outdoor air system (DOAS) unit, it is feasible to place new equipment within the footprint of the removed equipment. This would negate the need to reconfigure the arrays. This would also require confirmation when equipment is specified.

Solar Potential

Analysis of the sites was performed to determine if solar access and typical weather conditions are suitable for solar photovoltaics. The variables of interest included global horizontal irradiance (GHI), direct normal irradiance, diffuse horizontal irradiance, and ambient temperature. Data from NREL's National Solar Radiation Database (NSRDB) was used to assess typical conditions for the proposed site. These variables are necessary for calculating the irradiance available to PV arrays and can serve as a proxy for preliminary assessments of solar PV production. GHI is the total amount of sunlight available at the Earth's surface, including both the direct and diffuse components of sunlight. The average annual GHI for Massachusetts is 3.8 kWh/sq.m/day. The map below indicates the average daily horizontal irradiance available across Massachusetts and neighboring states.



Through the data obtained from the NSRDB, an annual profile of solar irradiation was created, as shown in the figure below. Due to the site locations, photovoltaic solar systems have the potential to produce a significant amount of electrical energy. While high ambient temperatures can reduce a PV array's power output, the maximum average monthly temperature for Massachusetts is only three degrees Celsius higher than standard testing conditions for PV modules. At the maximum temperature of 96.8 degrees Fahrenheit, module performance would only be expected to depreciate by 1.2%. These factors combine to make the sites suitable location for solar PV systems.



To understand the site solar potential, Helioscope models were created for each site. This is the same tool utilized by Ameresco in their previous solar study. The higher solar potential found in our study can be attributed to the continued advancement in solar panel efficiency. The models used 450W modules. The total solar potential of each school, using 2022 solar panels, is shown in the chart below. The existing solar arrays at Dallin, Peirce, and Ottoson take up a majority of the rooftop square footage, leaving limited space for new installations. Given that those installations are set to stay installed through 2035, the actual install potential was recalculated. The "Actual Install Potential" column reflects the amount of solar that could be installed but should be verified when the system is designed. Lastly, the EUI Offset shows the equivalent offset from the actual install potential.

Site	2022 Rooftop PV Potential	Existing PV Install	Actual Install Potential	EUI Offset
Bishop Elementary School	187 kW	-	187 kW	14
Brackett Elementary School	191 kW	-	191 kW	12
Dallin Elementary School	271 kW	120 kW	69 kW	4
Hardy Elementary School	226 kW	-	226 kW	14
Peirce Elementary School	198 kW	80 kW	70 kW	5
Ottoson Middle School	613 kW	230 kW	341 kW	8

For Option 1 (VRF), to achieve a net zero energy building at the target EUI of 45, then the average solar array for each of the six schools would be 1034 kW in size. For Option 2 (geothermal), to achieve a net zero energy building at the target EUI of 22, the average solar array for each of the six schools would be 521 kW in size. In no case is the amount of feasible rooftop solar enough to fully offset the predicted EUI of either system.

Clean Energy Procurement

In Massachusetts, electric and/or gas customers can compare pricing among competing energy commodity providers. Energy reforms and market competition bring lower, more flexible energy prices with new service offerings designed to attract and keep customers. These reforms are the result of energy market deregulation, where consumers are empowered to compare rates, services, and contract terms, and then choose the options that are best for them.

Purchasing renewable energy could provide a relatively simple way to offset electricity emissions for the Town. Renewable energy can often be purchased directly from the customer's load-serving utility, or from a specialized service provider. This is a widespread and familiar compliance strategy for many organizations with renewable energy goals. This could be an improvement made in the interim period between the present and full electrification. This strategy could continue to be employed post-electrification, to offset the emissions of electricity from the grid until the point at which the grid is completely clean. Eversouce and the State of Massachusetts have made commitments to green the grid by 2050.

Clean Energy Recommendations

Initial area evaluations indicated that Town would need to accommodate approximately 3-6 MW of roof-mounted and ground-mounted solar PV to fully offset energy consumed across the 6 schools. In cases where on-site generation is limited by technical or economical limitations, procurement strategies should be adopted to reduce emissions from purchased electricity.

Reaching net zero energy on site is not likely feasible. The potential for a community solar installation, which would be sized to total any required solar that could not be accomodated at the six school sites, was then put forth. The size of such an installation would have been more than a few acres and such real estate is not available in the town.

For the Town to reach its net zero emissions goal, with the constraints above, the best option could be clean energy procurement. This solution would allow the Town an intermediate solution until the grid is 100% clean. The approach would remain: pay attention to energy efficiency first, designing and maintaining electrified schools with the lowest possible EUI. Then, the Town would procure clean energy to offset the GHG emissions associated with the grid electricity used. As the grid becomes cleaner, the amount of clean energy required as an offset would decrease until it is no longer necessary.

Building Operations & **Performance**

With the financial investment required for these facilities, hands-on commissioning and optimization for these future high-performance buildings is a *must-do.* Optimized commissioning must be performed for all energy consuming and energy producing systems in the building. Building envelope pressure testing (blower door testing) and thermal scanning is recommended to establish baseline infiltration levels and will help to identify specific areas where improvements are needed.

The level of service and expectations of commissioning should be above and beyond standard commodity commissioning procedures typically seen in the industry. The commissioning effort must include true optimization of system sequences, set-points, and schedules to ensure energy performance goals can be realized. It is critical to plan commissioning (Cx) time in the overall construction schedule and include the appropriate contractor representation to make Cx successful, with the goal of obtaining the required reduction results as soon as possible.

A measurement and verification plan can validate the implemented energy conservation measures obtained the desired energy reductions. In this approach, the contractor obtains and reviews the monthly energy data (electricity and natural gas) provided by the Town for 15 – 18 months post construction as compared to the energy model. As conditions, schedules, and set-points tend to change over time, the energy performance of the building will be affected. The energy data should be verified at least every 6 months.

The plan must review the sub-metered data from the solar PV system. This plan must also include a review of the building's operations. This includes reviewing actual operating hours versus those modeled. After a sufficient time for operations to settle in, the Town must provide 12 months of verified energy data suitable for certification requirements as needed. The overall approach would be in accordance with IMVP (International Measurement and Verification Protocol) Guidelines Option C & D.

PHASE III
INVESTMENT PLAN

PHASE III OBJECTIVES

This project phase uses the analysis from the two phases prior to develop priorities which are placed on a timeline. Recalling that the goal of the Town is to renew aging HVAC systems, achieve full electrification, and improve air quality by 2050, this section details a strategic roadmap.

The analysis between the systems factors in order of magnitude first cost estimates, anticipated annual operating costs, and carbon emissions potential to establish a life cycle cost investment. There are also utility incentives and federal tax dollars that may be available depending on the option chosen. For each site, three alternatives are considered.

The three options are:

1. Variable Refrigerant Flow (VRF) System
2. Ground Source Heat Pump System
3. Business as Usual: Hot Water Heat with full DX Air Conditioning (Fossil Fuel Remains)

The first and second options are those that were proposed as viable all-electric HVAC systems that would provide full heating and air conditioning to all buildings in an energy efficient manner. The design details for these systems are detailed in Appendix A.

The third option represents the business-as-usual case. In this case, the existing natural gas heat remains and electrification is not achieved. The costs associated would be system replacements when systems reach end of life. To make this case comparable to the others, which provide complete heating and cooling, full air conditioning via DX cooling is included. This option demonstrates essentially the minimum cost to the Town to continue to run these six schools over the 30 year period analyzed.

Ultimately, this section provides the Town with the data needed to evaluate the options to meet the goals laid out in the Net Zero Action Plan and Electrification & Air Quality Master Plan. A timeline for renewal is proposed based upon Town priorities which, along with initial costs required to install either system, gives the Town a tool for mapping out the future projects and financial investment required to reach its goals.

Life Cycle Cost Analysis Methodology

LCCA inputs included first cost data, utility costs, inflation rate, and estimated maintenance. The first cost data come from the cost estimations of the VRF and Ground Source Heat Pump Systems described in further detail in Appendix D. Utility data costs were calculated using the 2022 blended utility rates provided by the Town, $0.25/kwh and $1.15/therm, for electricity and natural gas, respectively. An inflation rate of 6% was applied to natural gas and 5% was applied to electricity. Maintenance was estimated on a square foot basis per system and subject to market escalation, which was estimated at 2% annually.

Replacement costs at year 20 are a percentage of the first cost, escalated out to 20 years. The percentage applied depends on the average lifespan of system components, and the total estimated amount of equipment that would be replaced at that time.

Life Cycle Cost Analysis Trends

Studying the results, a few trends emerge:

- In every case, when looking at first cost of the HVAC system alone, the ground source heat pump option is more expensive than the variable refrigerant flow option. The existing heat and DX cooling option first cost falls between that of VRF and geothermal.
- When looking at life cycle costs, with no incentives, the ground source heat pump system becomes less expensive than the VRF system in all but one case (Peirce) where the systems cost the same amount.
- Taking market and legislative conditions into account, the Inflation Reduction Act and Mass Save expected incentives were applied. Based on the incentives available, the ground source heat pump system becomes significantly less expensive, whereas the VRF system qualifies for fewer incentives, so costs decrease only slightly. Notably, with incentives, the VRF system cost is comparable to the cost of the existing heat and DX cooling option, which remains more expensive for all schools than the geothermal option. The savings in today's dollars from incentives when totaled across the six schools are $1.3 million for VRF and $27.5 million for the ground source heat pumps.

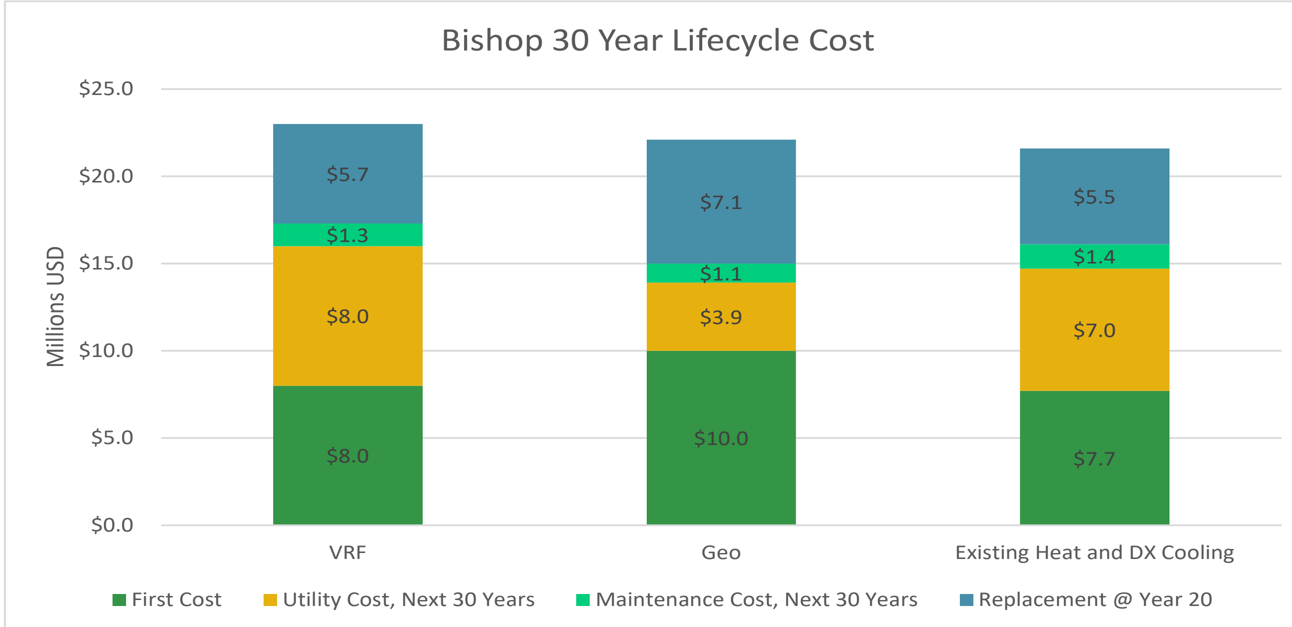
It is critical that the Town consider life cycle costs when evaluating viable electrification options. Selecting a less efficient system or looking strictly at first cost alone could lead to a choice that spends more money than is necessary. Looking at the group of six schools, in today's dollars and with incentives, the difference in life cycle costs between the VRF and ground source heat pumps options is $34.3 million. This is the equivalent of 635 teachers' annual salaries, using the average Massachusetts teacher's salary of $54,000.

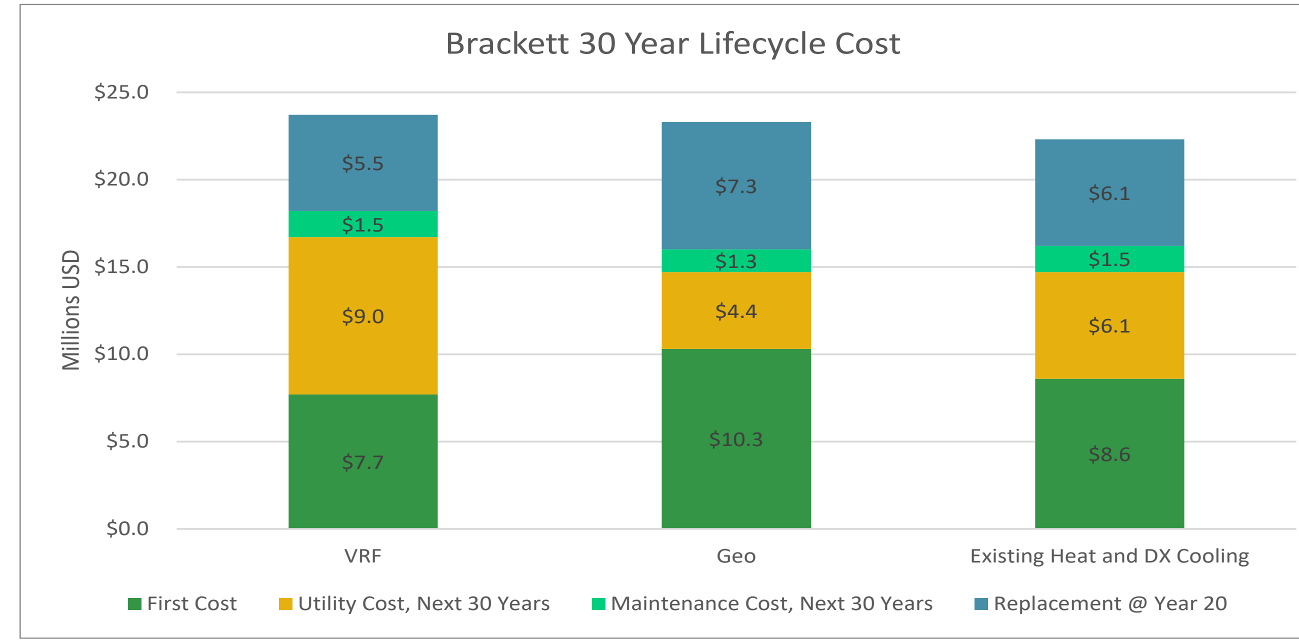
Life Cycle Cost Analysis Data

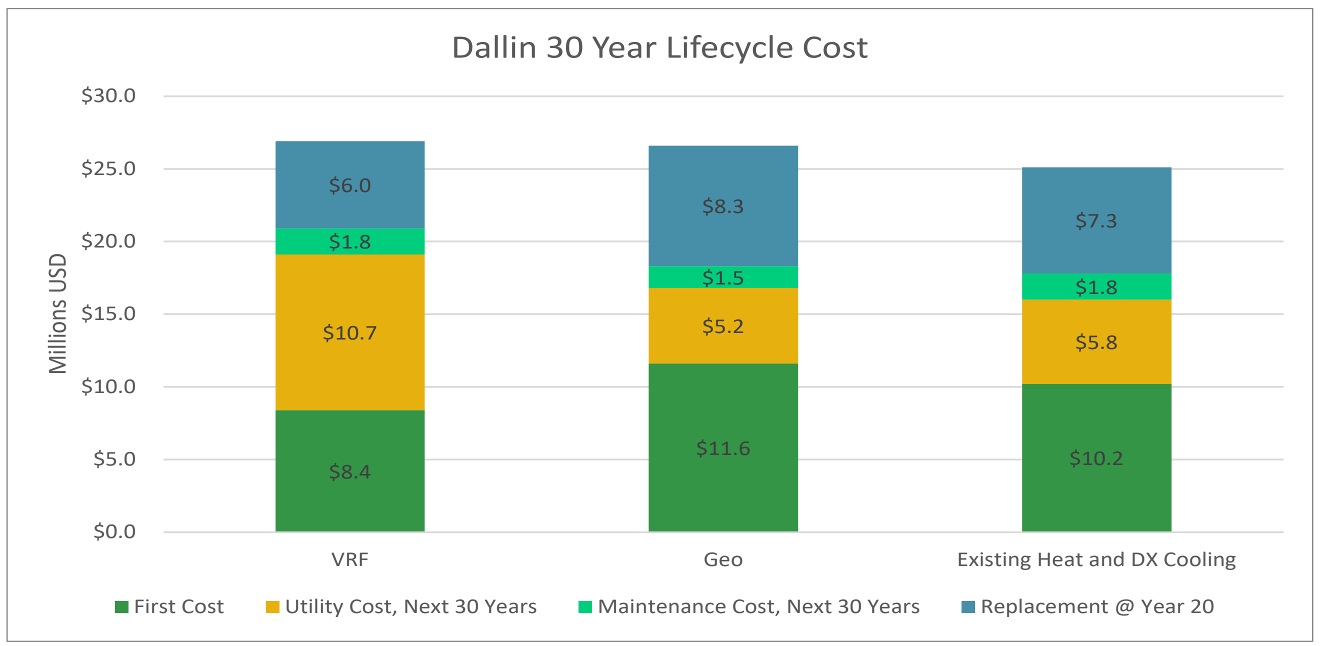
The charts and graphs on the following page offer the Town the ability to consider the options through several lenses. In every instance, the "In-Kind" case is shown as a point of comparison. It is essentially a do-nothing, business as usual case where on-site fossil fuels remain. It will not achieve the Town's stated goals of electrification and improved air quality.

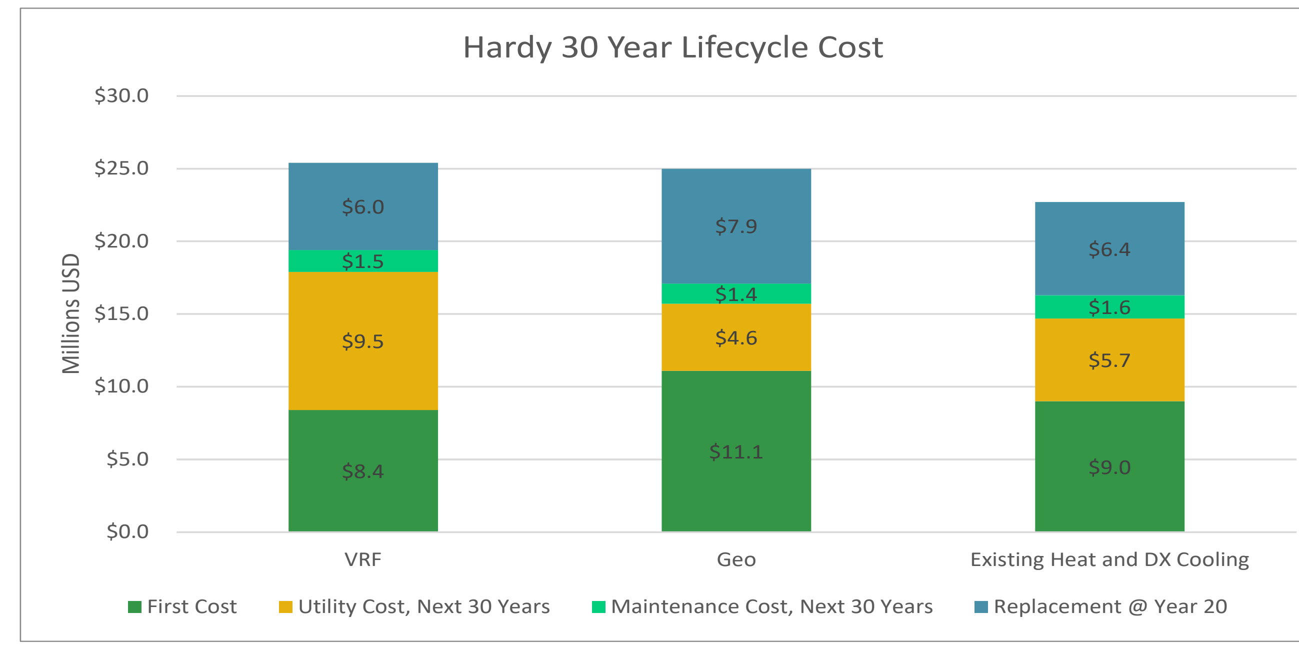
The bar charts build a picture of costs, starting with initial investments that would occur in year one of any given project, followed by a series of 30-year life cycle costs. Complete life cycle costs for are shown first, followed by the same case with IRA incentives applied, and ending with the addition of Mass Save incentives.

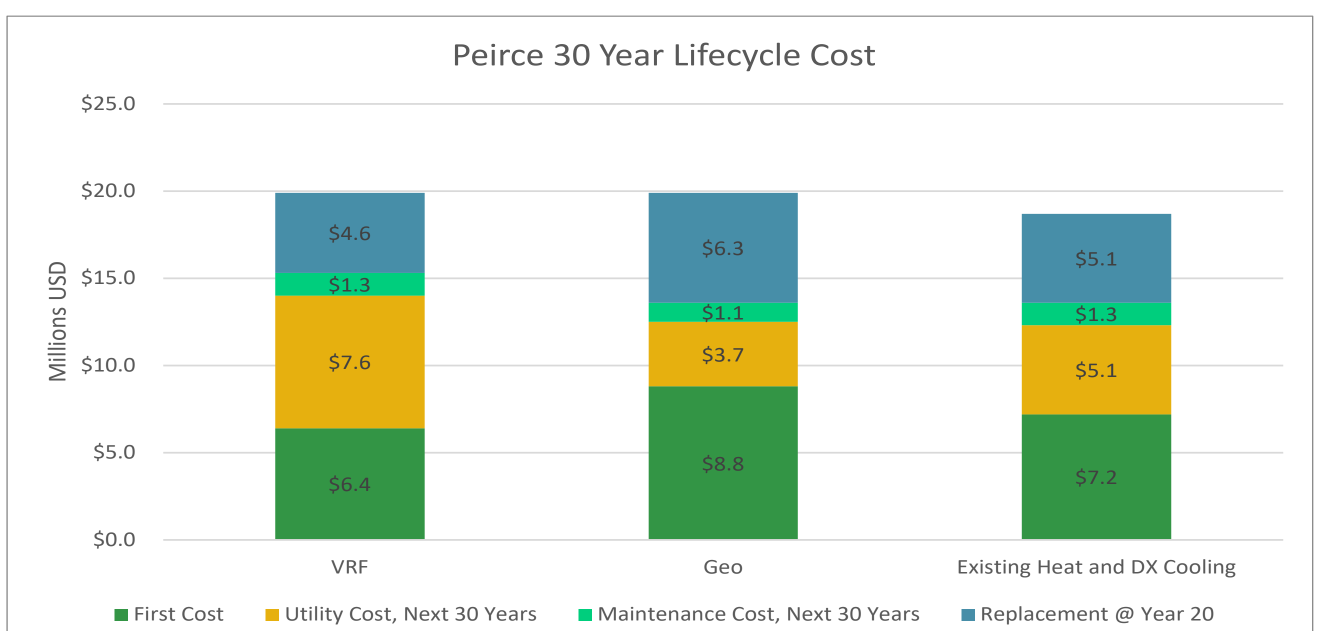
30 YEAR LIFE CYCLE COST

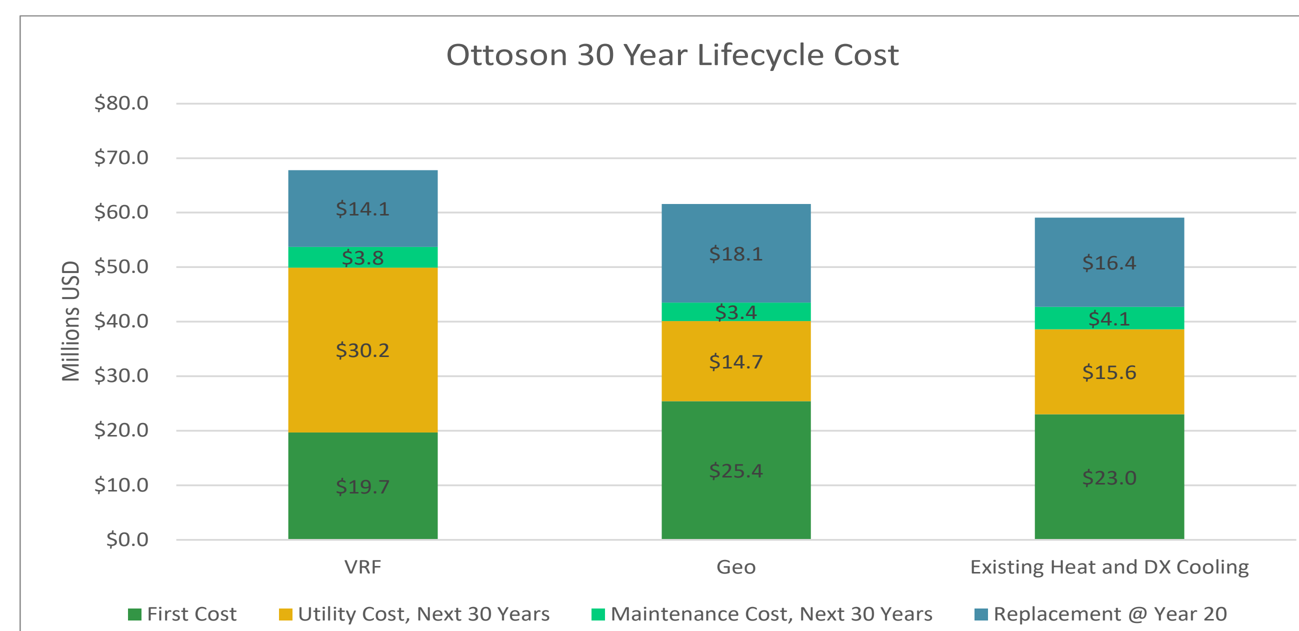




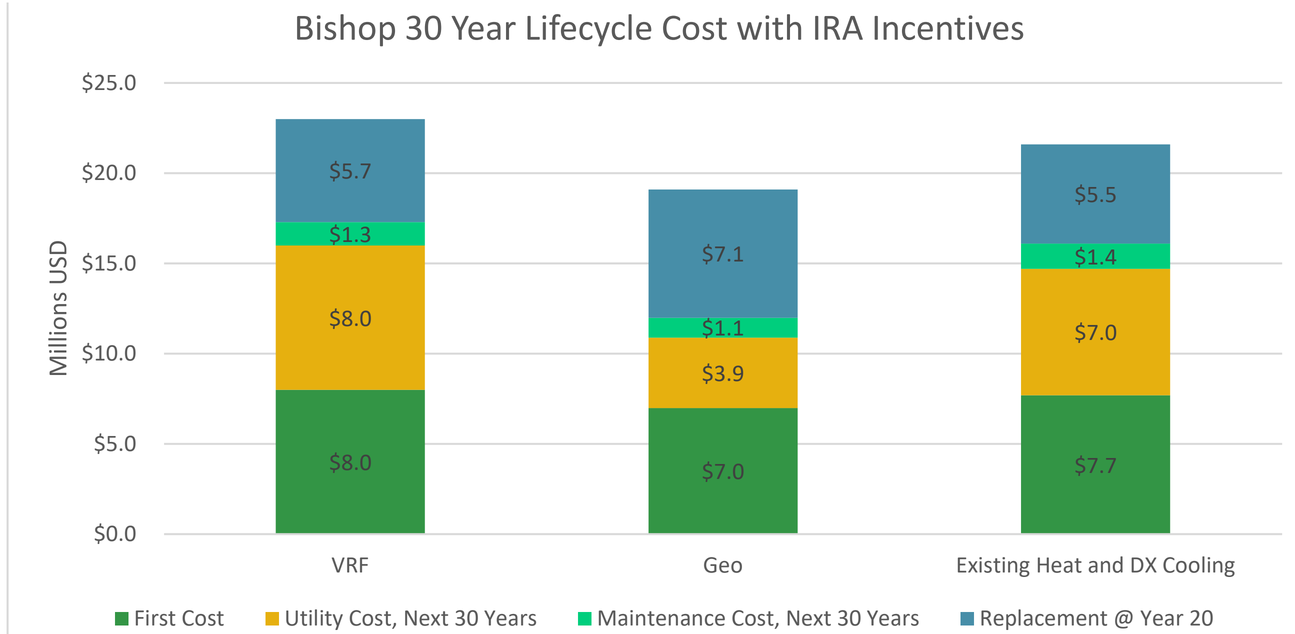


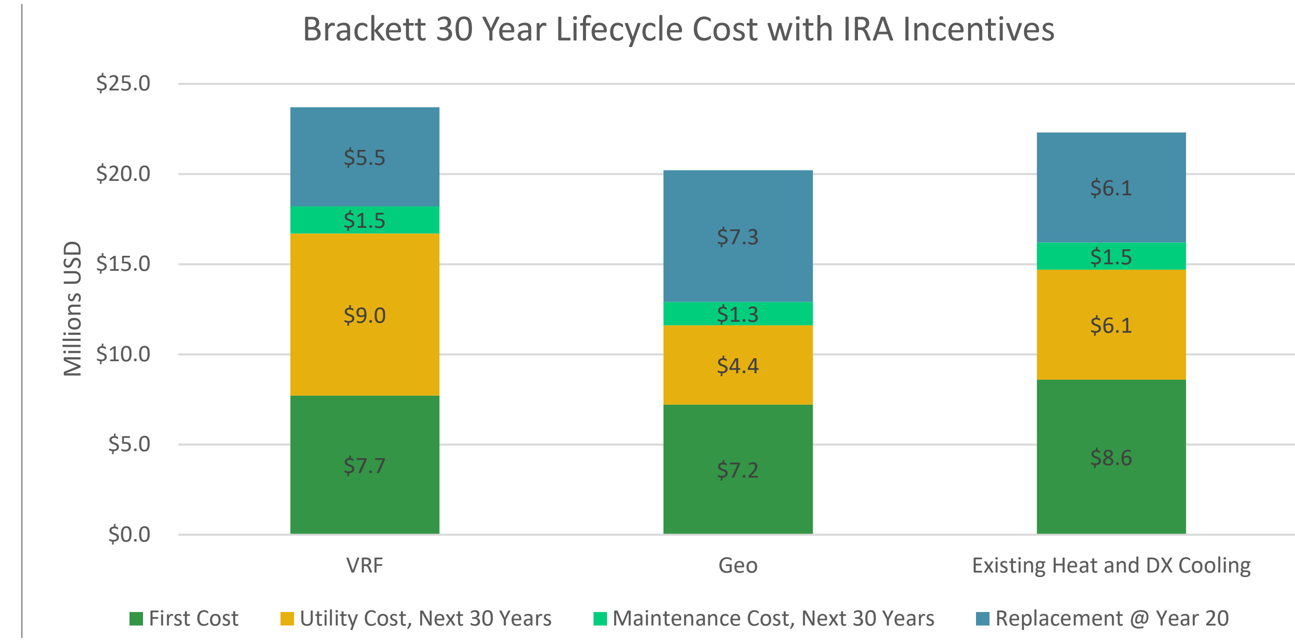


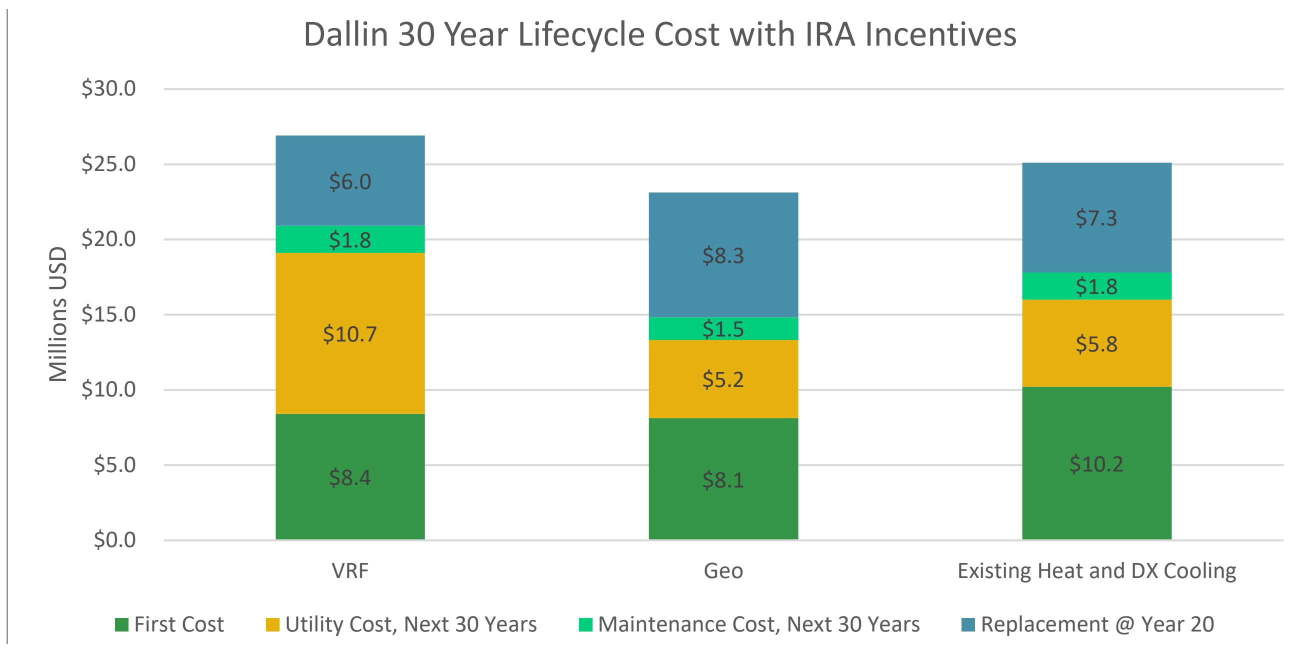


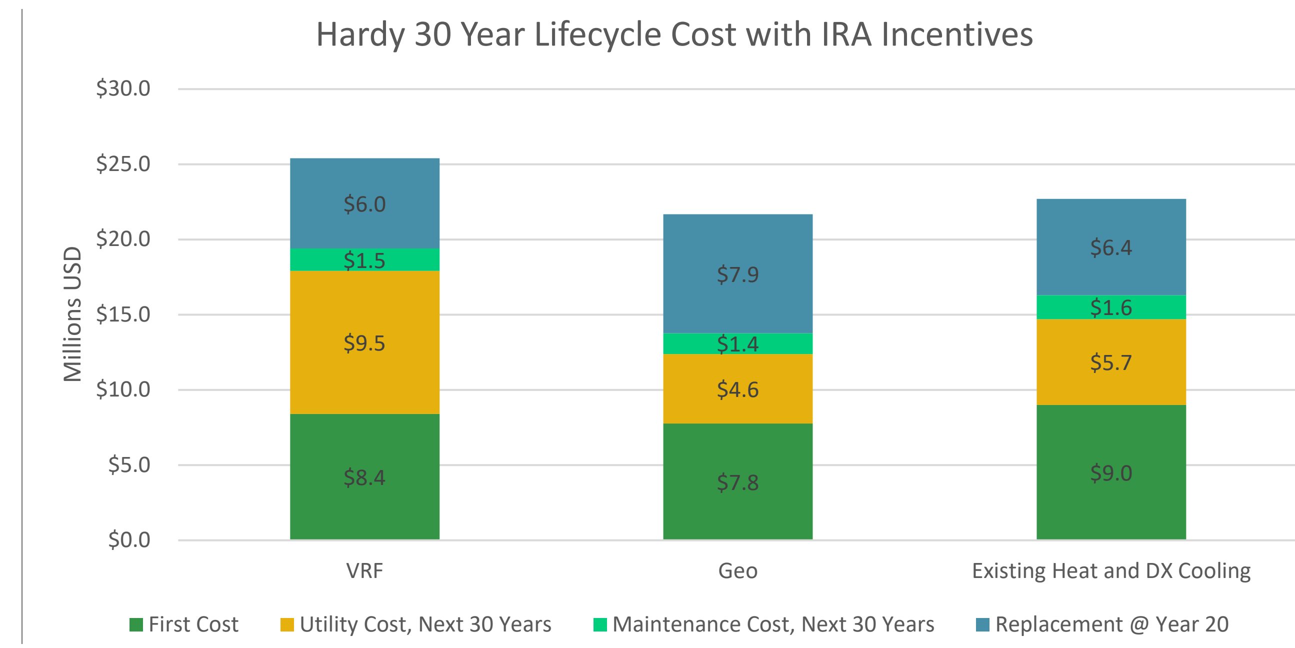


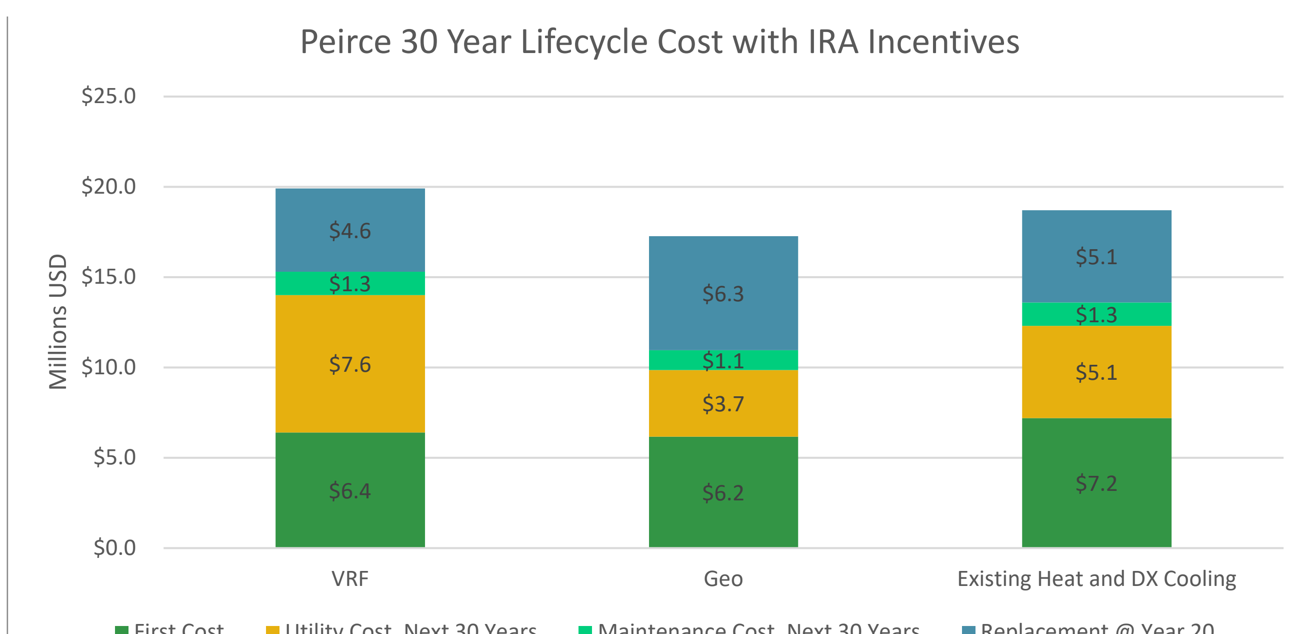
30-YEAR LIFE CYCLE COST WITH IRA INCENTIVES

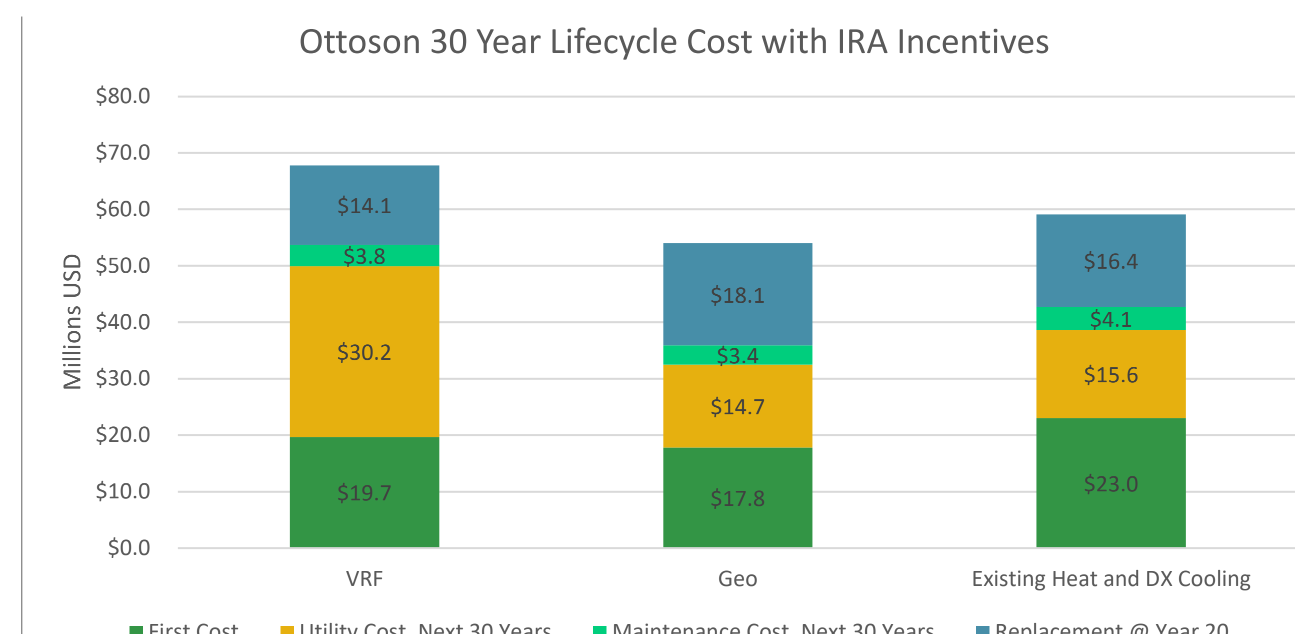




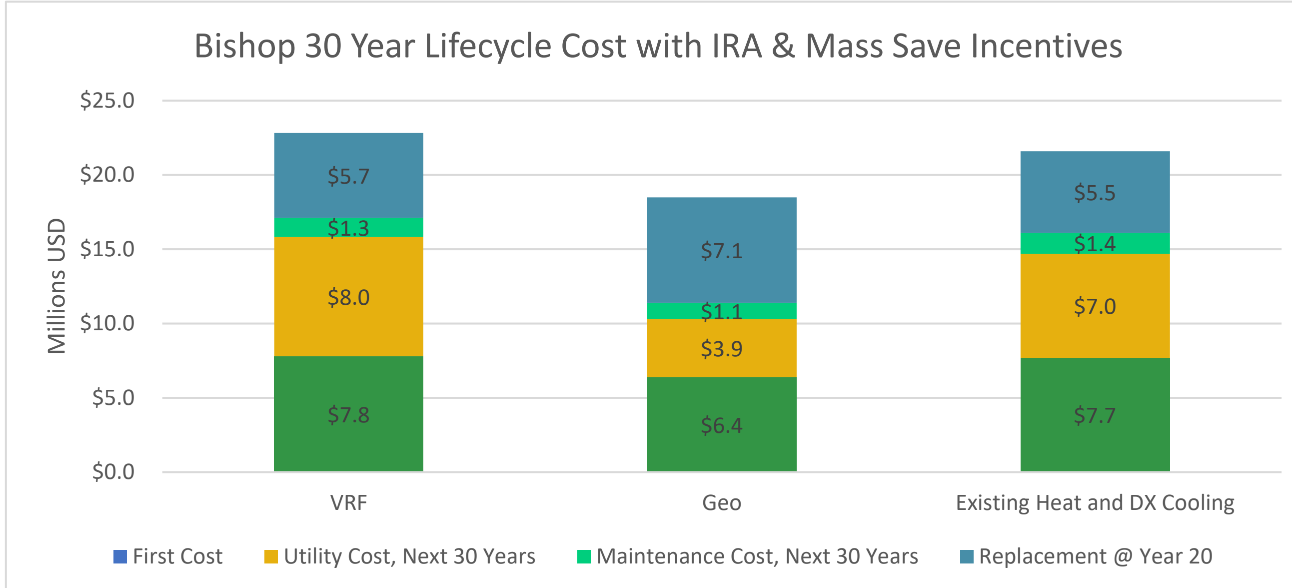


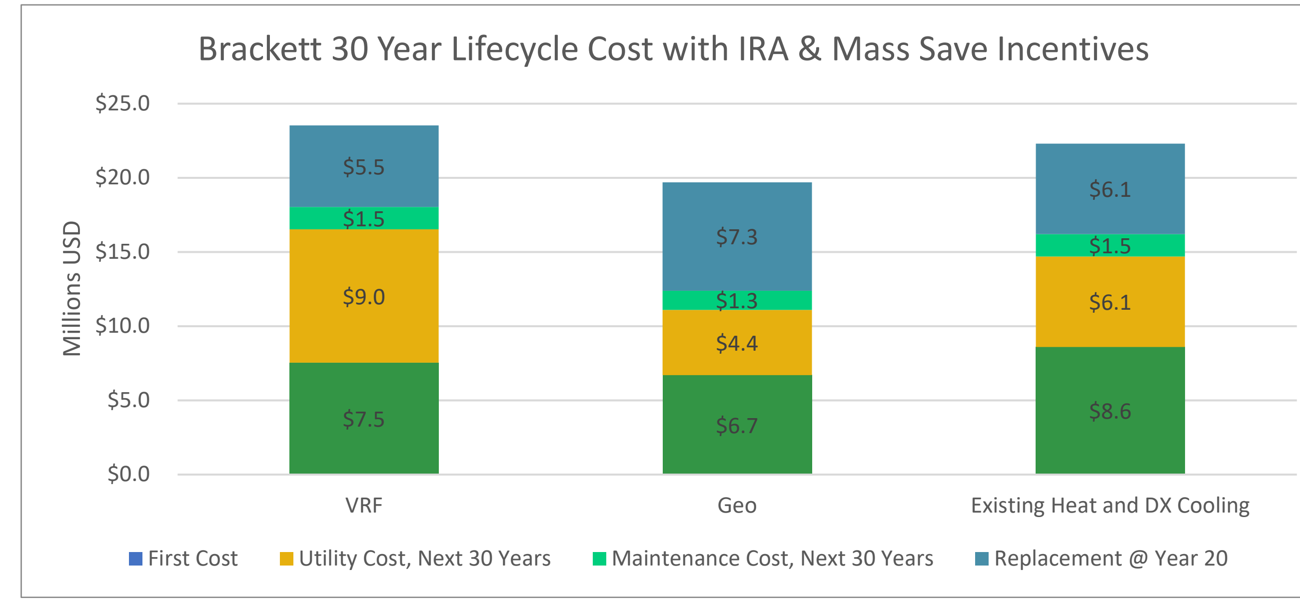


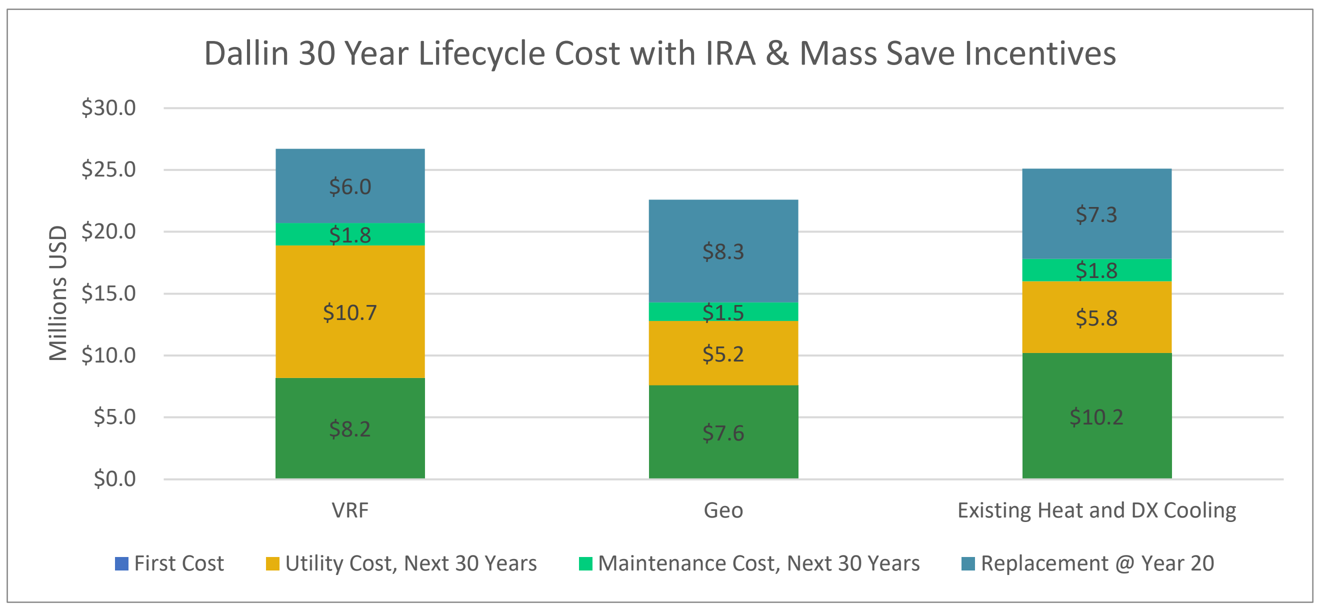


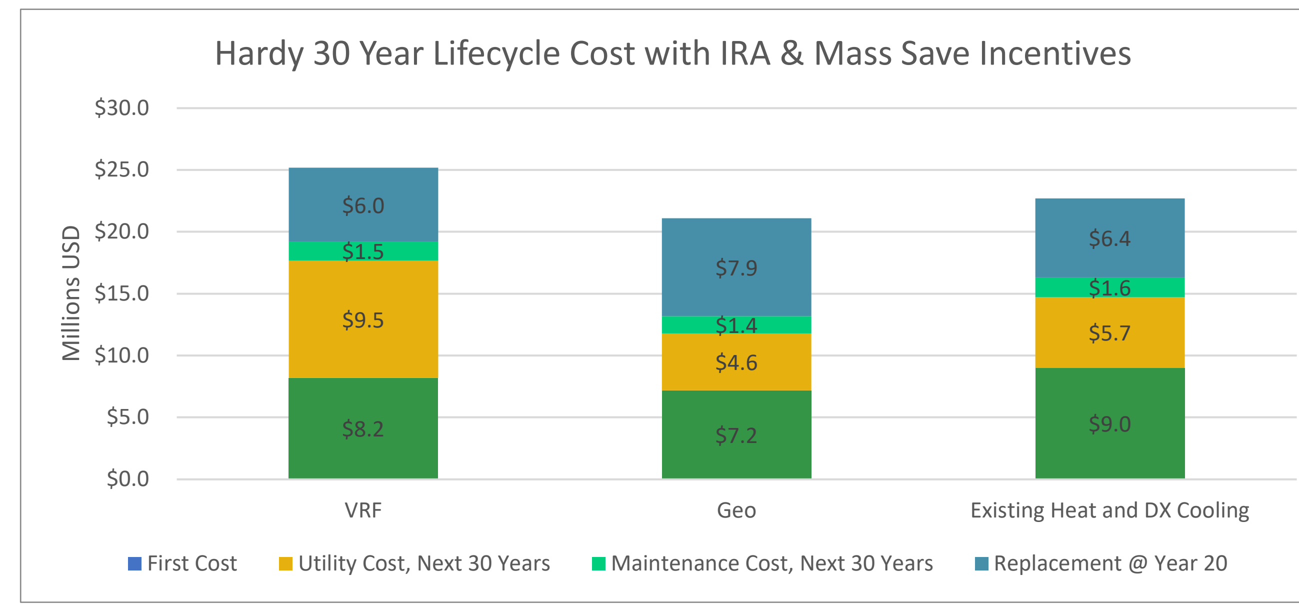


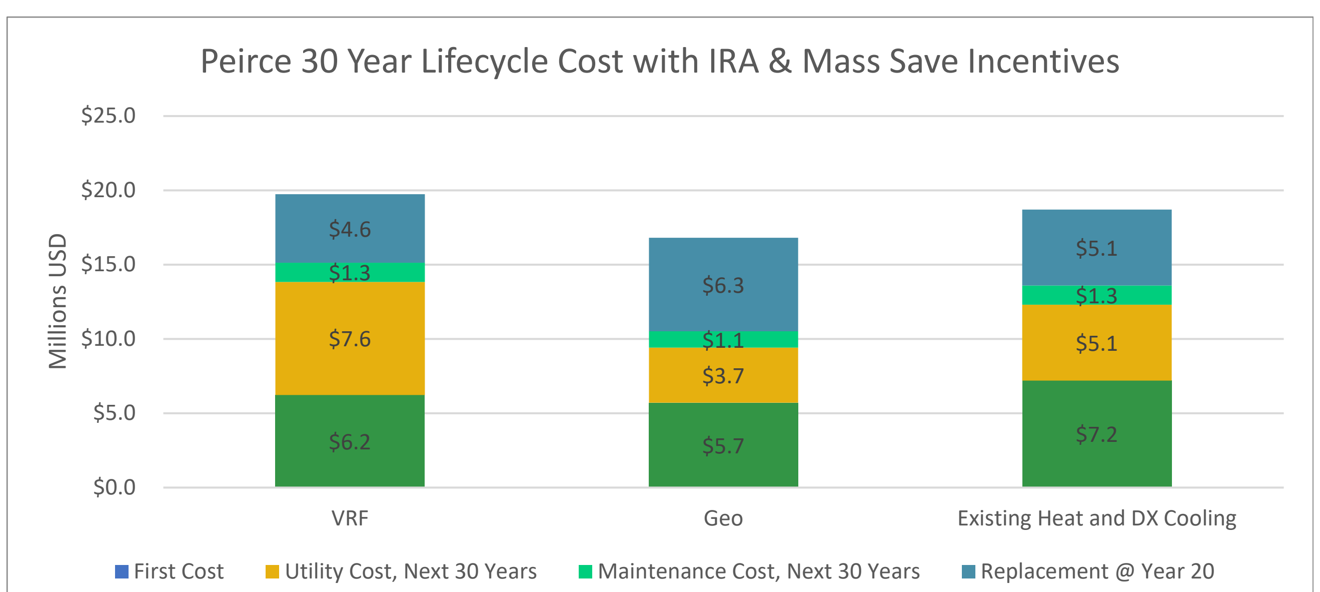
30-YEAR LIFE CYCLE COST WITH IRA & MASS SAVE

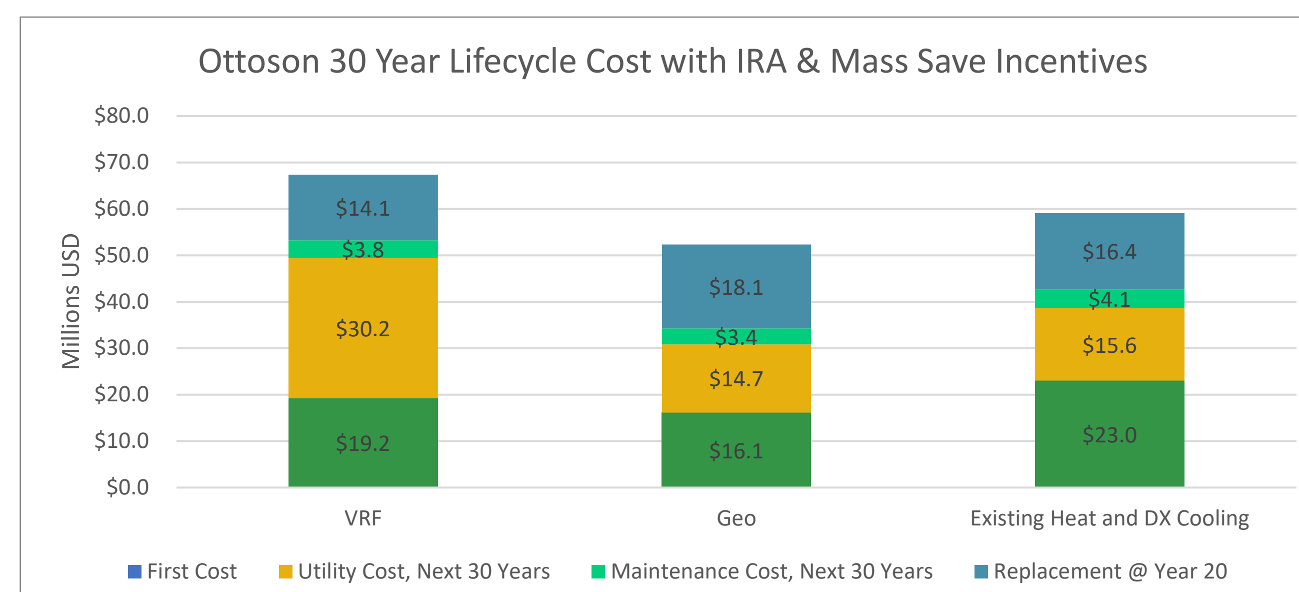












Incentives

Utility Incentives

Massachusetts offers a robust utility rebate and incentive program called Mass Save that is administered through the major utility providers (National Grid, Eversource, etc.). There are several paths available within this program. The local utility should be included when embarking on any renovation project to determine if any energy efficiency measures can be utilized to receive rebates or incentives. The program details are found here: https://www.masssave.com/en/saving/business-rebates/new-buildings-and-major-renovations/whole-building-energy-use-intensity-reduction

PATH 2: WHOLE BUILDING EUI REDUCTION APPROACH	
Customer Incentives	
Incentive rate range (based on EUI % reduction)	$0.35/sf - $1.25/sf
Space Heating Heat Pump Adder	
• Air Source Heat Pumps:	$800/ton
• Variable Refrigerant Flow (VRF):	$1,200/ton
• Ground Source Heat Pumps:	$4,500/ton
Technical Assistance	up to 75% cost share (capped at $20,000 per Sponsor)
Verification Incentive	50% of fee up to $10,000

Percent EUI Reduction	
25.0% and above	$1.25/sf
20.0% - 24.9%	$0.75/sf
15.0% - 19.9%	$0.50/sf
10.0% - 14.9%	$0.35/sf

Incentives are summarized in the figures above. With 441,000 SF across the six schools and an expected reduction of at least 50-70%, there is potential to receive an incentive of ≈$550,000 in total ($1.25/SF). If geothermal heat pumps are selected, the full $1.25/SF is expected. If VRF is selected, the EUI reduction would be half as much as in the geothermal case, so the estimated incentive is lower. The calculations in the chart below estimated a $1/SF for VRF. The following incentives could be anticipated for each of the schools.

Additionally, there are the Space Heating Heat Pump adders. Both electric HVAC systems considered are eligible at $1,200/ton for VRF and $4,500/ton for ground source heat pump. The estimated tonnage from this study was used to calculate the adder incentives.

With both incentive types, the expected Mass Save incentives are estimated to total:

	Variable Refrigerant Flow	Ground Source Heat Pump
Bishop Elementary School	$ 169,000	$ 599,000
Brackett Elementary School	$ 151,000	$ 548,000
Dallin Elementary School	$ 189,000	$ 529,000
Hardy Elementary School	$ 195,000	$ 586,000
Peirce Elementary School	$ 159,000	$ 459,000
Ottoson Middle School	$ 438,000	$ 1,655,000

All numbers are estimates based on the schematic designs and would need to be reassessed after Construction Drawings are completed. There are also opportunities to engage the students, faculty, and staff in the energy conversion efforts in these schools through the Mass Save program. More on those programs here: https://www.masssave.com/en/learn/activities-and-school-resources

Inflation Reduction Act

Within the period this study was completed, the United States House and Senate passed the Inflation Reduction Act. The $740 billion package includes around $370 billion for climate change and energy efforts. These provisions could result in additional funding for the Town's electrification goals.

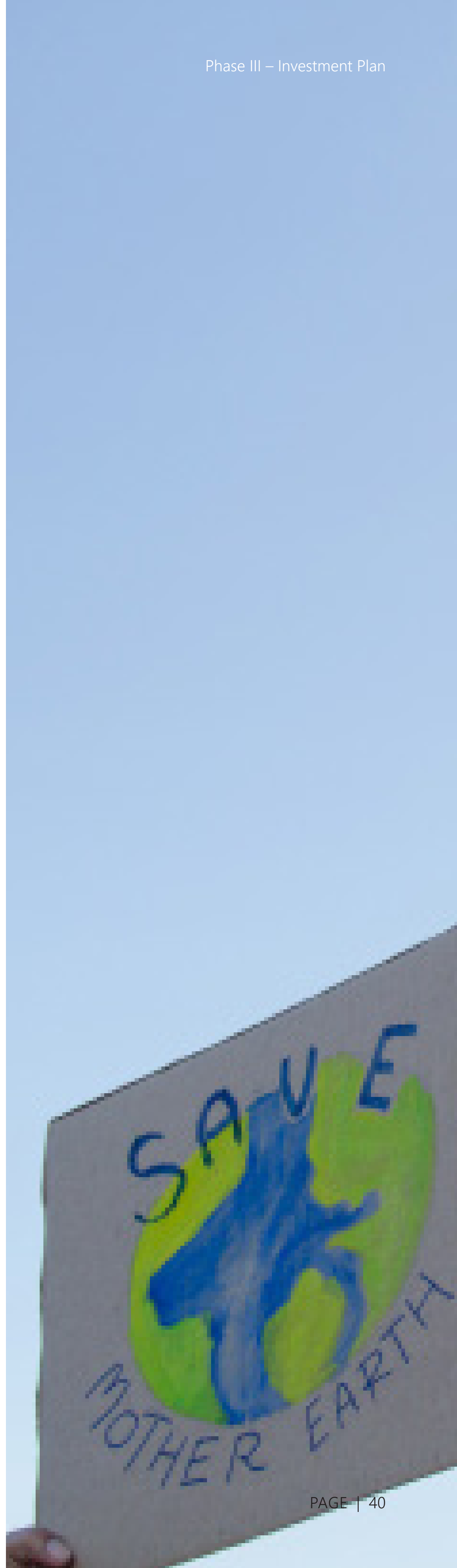
Public K-12 School Systems, Universities, and Municipal City/Counties are tax exempt and therefore qualify for the direct-payment option of the investment tax credit (ITC) including ground source heat pumps and solar. These incentives should apply to any projects placed into service after December 31st, 2022, which would include all six projects. For the Town of Arlington, the expected impact would include:

- ITC of 30% for projects that commence construction on or before 2032 and then phases down to 26% for projects that begin construction in 2033 and 22% for projects that commence construction in 2034. The ITC will apply as long as the property has begun construction before January 1, 2035.
    - If the phasing in the following section is adopted, then all six school projects would occur before that 2035 cut off.
- The "Direct-Payment" reimbursement similarly applies to the Solar Array, essentially providing a 30% reimbursement for installing and owning photovoltaic arrays.

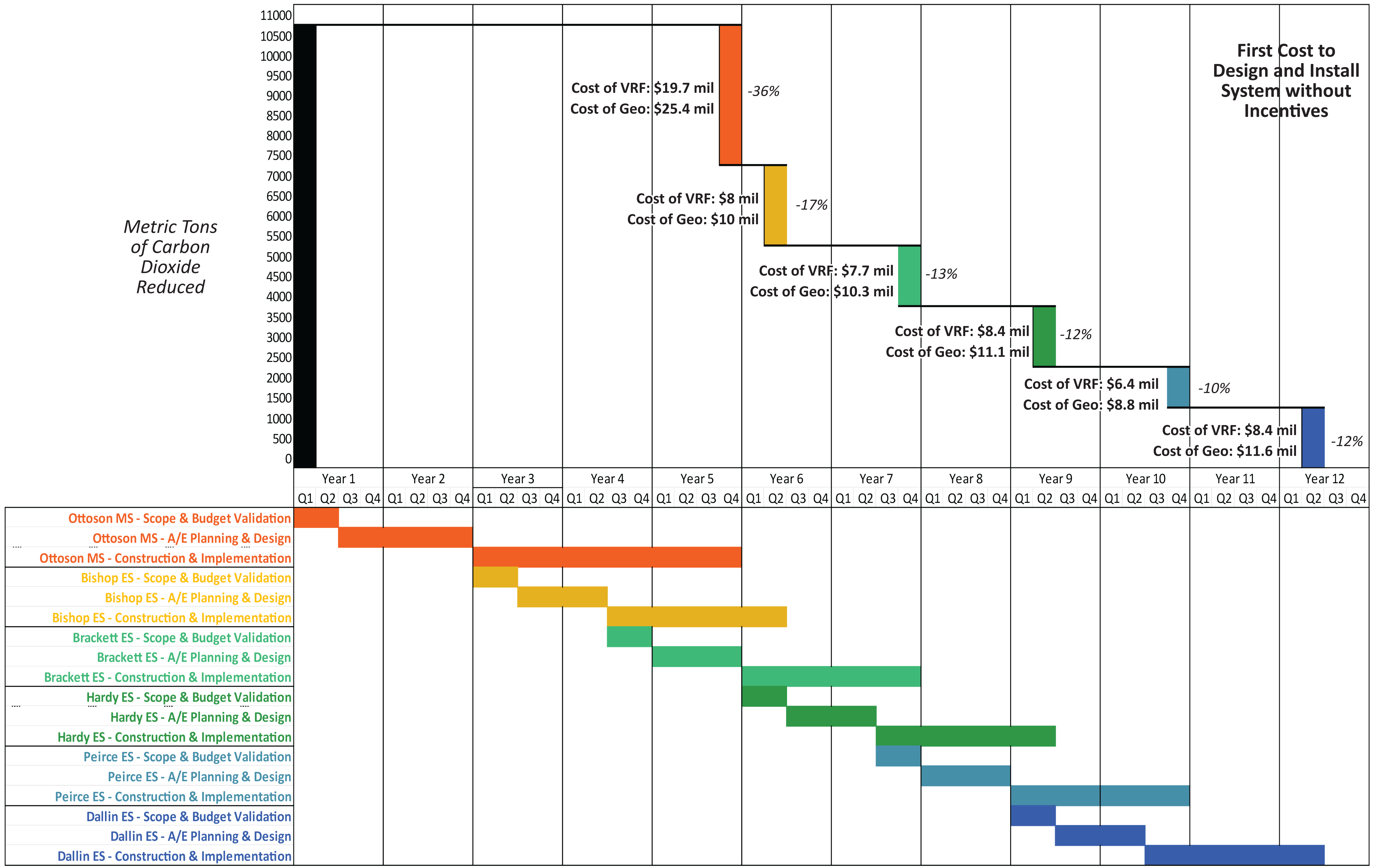
The chart below reflects the expected total incentives per system:

	Variable Refrigerant Flow	Ground Source Heat Pump
Bishop Elementary School	$ 0	$ 3.0 million
Brackett Elementary School	$ 0	$ 3.1 million
Dallin Elementary School	$ 0	$ 3.5 million
Hardy Elementary School	$ 0	$ 3.3 million
Peirce Elementary School	$ 0	$ 2.6 million
Ottoson Middle School	$ 0	$ 7.6 million

Analysis with these incentives is included below. Note that these numbers are estimates and would require review by the Town's legal, accounting, and tax advisors to confirm.



STRATEGIC ROADMAP



The main findings of the Master Plan conducted are summarized in the Strategic Roadmap to Electrification. The analysis presented optimized the ranking and sequencing of projects based on order of magnitude of cost, emissions reduction potential, and need for infrastructure renewal. These recommendations are detailed in the Phase III section of this report. While the established goal of electrification by 2050 may seem far in the future, when considering the project scope to retrofit six schools, factoring in the design and construction period, as well as the planning for funding outlays of this magnitude in advance, the Town ishould initiate this process early. The chart above is the culmination of all three phases. It shows the recommended project phasing, the impact project completion would have on site emissions in the Town of Arlington, and the first cost for each viable, fully electrified option.

FUNDING FLOWS

	Variable Refrigerant Flow		Ground Source Heat Pump	
	Spend	**Rebate/Incentive**	**Spend**	**Rebate/Incentive**
Year 1				
Ottoson MS	$ (19,700,000.00)		$ (25,400,000.00)	
Year 2				
Year 3				
Bishop ES	$ (8,000,000.00)		$ (10,000,000.00)	
Year 4				
Brackett ES	$ (7,700,000.00)		$ (10,300,000.00)	
Year 5				
Year 6				
Hardy ES	$ (8,400,000.00)		$ (11,100,000.00)	
Ottoson MS Mass Save Incentive		$ 438,000.00		$ 1,655,000.00
Ottoson MS IRA Incentive		$ -		$ 7,600,000.00
Year 7				
Peirce ES	$ (6,400,000.00)		$ (8,800,000.00)	
Bishop ES Mass Save Incentive		$ 169,000.00		$ 599,000.00
Bishop ES IRA Incentive		$ -		$ 3,000,000.00
Year 8				
Brackett ES Mass Save Incentive		$ 151,000.00		$ 548,000.00
Brackett ES IRA Incentive		$ -		$ 3,100,000.00
Year 9				
Dallin ES	$ (8,400,000.00)		$ (11,600,000.00)	
Year 10				
Hardy ES Mass Save Incentive		$ 195,000.00		$ 586,000.00
Hardy ES IRA Incentive		$ -		$ 3,300,000.00
Year 11				
Peirce ES Mass Save Incentive		$ 159,000.00		$ 459,000.00
Peirce ES IRA Incentive		$ -		$ 2,600,000.00
Year 12				
Dallin ES Mass Save Incentive		$ 189,000.00		$ 529,000.00
Dallin ES IRA Incentive		$ -		$ 3,500,000.00
Totals	$ (58,600,000)	$ 1,301,000	$ (77,200,000)	$ 27,476,000
Net Spend	**$ (57,299,000)**		**$ (49,724,000)**	

The table above demonstrates the first cost allocations and expected incentives for each system. First cost represents the cost for either system in year one of a project. For any incentives, disbursment is typically allocated one year after the project is completed. The delay reflects the estimated time required to conduct a cost segregation study.

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